Reconnaissance Report

Water Resources Study
Muddy River Watershed
Massachusetts

December 1992

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The purpose of this study was to identify flooding problems and allied water resource needs of the Muddy River Watershed, located in eastern Massachusetts in the communities of Boston, Brookline and Newton. Potential solutions to these problems and needs were evaluated based upon their benefits and costs, potential impacts on environmental and historic resources, and views of interested officials and individuals. The Muddy River flows through the heart of Frederick Law Olmsted's famed "Emerald Necklace" park system, one of the most carefully crafted park systems in the Nation. The major environmental problems associated with the Muddy River include poor water quality, expansion of Phragmites stands along a large percentage of the riverbank, and contaminated riverine sediments. The major causes of these problems are combined sewer overflows, illegal sewer connections, accidental oil spills, and general urban runoff. The potential solutions to the water quality problem include source control, in-stream treatment, aeration, and flow augmentation. The results of the study do not support further Federal participation by the Corps of Engineers since identified flood damage reduction measures are not economically justified.

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RECONNAISSANCE REPORT

WATER RESOURCES STUDY

MUDDY RIVER WATERSHED

MASSACHUSETTS

DECEMBER 1992

EXECUTIVE SUMMARY

The Muddy River drains 7.5 square miles of highly urbanized watershed located in eastern Massachusetts in the communities of Boston, Brookline and Newton. The river flows through the heart of Frederick Law Olmsted's famed "Emerald Necklace" park system, one of the most carefully crafted park systems in the Nation. This system provides picturesque scenery and accomodates many recreational pursuits, such as jogging, walking and picnicking, that are not normally available to the urban dweller. Flooding, poor water quality, and degraded riverine habitats prompted Congress to include funds to evaluate these problems in the Energy and Water Development Appropriation Act for fiscal year 1992.

The purpose of the reconnaissance study was to review water resources problems in the watershed, develop and evaluate plans to address those problems, and determine if further Federal involvement by the Corps of Engineers was justified.

Major flooding occurred along the Muddy River in August 1955 and October 1962, with lesser flooding occurring in March 1968. It is estimated that a repeat of the 1955 flood would cause approximately $ 3 million in flood damages. Studies of the watershed determined that this flooding is caused primarily by the flat channel gradient, restrictive culverts and insufficient channel capacity in some reaches. Several flood damage reduction measures, including culvert replacement and channel improvements, were evaluated to prevent a recurrence of these floods. However, it was determined that the cost of these improvements would exceed attributable flood control benefits, and further Federal involvement would not be economically justified.

The major environmental problems identified along the Muddy River include poor water quality, contaminated riverine sediments, and expansion of Phragmites stands along a large percentage of the riverbank. Based on the development and evaluation of a significant amount of data concerning water and sediment quality (presented in Appendices C and D), it was determined that the major causes of these problems are combined sewer overflows, illegal sewer connections, accidental oil spills and general urban runoff. Potential solutions to the water quality problem include source control, in-stream treatment, aeration, and flow augmentation. In addition, removal of contaminated sediments and implementation of Phragmites control measures would improve the overall riverine environment.

The results of the reconnaissance study do not support further Federal participation by the Corps of Engineers since identified flood damage reduction measures are not economically justified. In addition, the majority of the river, specifically in the principal damage area, does not meet minimum flow criteria established for Corps participation. It is, however, suggested that information concerning environmental problems and potential solutions be considered in any future studies of the Muddy River. Particularly in the event that a local Sponsor desires to participate with the Corps in cost shared feasibility studies of the river as directed in the Energy and Water Development Appropriation Act for fiscal year 1993.

WATER RESOURCES STUDY
MUDDY RIVER WATERSHED
MASSACHUSETTS

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SECTION I

INTRODUCTION

Flooding, poor water quality, degraded riverine habitats and other related water resource problems along the Muddy River in Massachusetts prompted concerned individuals, citizens groups and local officials to seek methods of solving these problems. In addition to community action activities, these individuals and groups contacted Federal and State officials for assistance in solving these problems. As a result, funds to prepare this reconnaissance study were provided in the Energy and Water Development Appropriation Act for fiscal year 1992.

STUDY AUTHORITY

This study was conducted under authority contained in a Resolution of the Senate Committee on Public Works, adopted September 12, 1969, which states:

> "That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby requested to review the report on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining the feasibility of providing water resource improvements for flood control, navigation and related purposes in Southeastern New England for those watersheds, streams and estuaries which drain into the Atlantic Ocean and its bays and sounds in the reach of the coastline of Massachusetts, Rhode Island and Connecticut southerly of, and not including, the Merrimack River in Massachusetts, to, and including, the Pawcatuck River in Rhode Island and Connecticut, with due consideration for enhancing the economic growth and quality of the environment."

PURPOSE AND SCOPE

The purpose of this study was to identify flooding problems and allied water resource needs of the Muddy River Watershed. Potential solutions to these problems and needs were evaluated based upon their benefits and costs, potential impacts on environmental and historic resources, and views of interested officials and individuals. The results of this analysis were then used to establish the advisability of further Federal assistance in providing solutions to identified problems and needs.

STUDY AREA

The Muddy River watershed, shown on Plate 1, is located in eastern Massachusetts in the greater metropolitan Boston area. The majority of the watershed is located in the City of

Boston and town of Brookline, with a small portion being located in the City of Newton. The river has a total drainage area of about 8.6 square miles. The upper watershed is primarily residential with some commercial areas, while the lower watershed is characterized by high density residential, institutional and commercial development. Most of the watershed is relatively flat to gently rolling, and elevations vary from near sea level at the mouth of the river to between 200 and 300 feet at numerous points along the watershed boundary.
The Muddy River, a 3.5 mile long urban waterway, originates at Jamaica Pond and flows in a general northeasterly direction to its confluence with the Charles River. The river flows through the heart of Frederick Law Olmsted's famed "Emerald Necklace", one of the most carefully crafted park systems in America. The park provides picturesque scenery and recreational activities, such as walking, picnicking and wildlife observation, that are not always accessible to the urban dweller. The river and adjacent park lands are situated next to many residential neighborhoods as well as many prominent Boston institutions and businesses, including some of the areas' finest museums, hospitals and universities.

Although a preliminary review of the watershed indicated that the primary water resource problems occur along the main stem of the river, it was determined that the entire drainage area must be considered to effectively evaluate the problems and opportunities of the area.

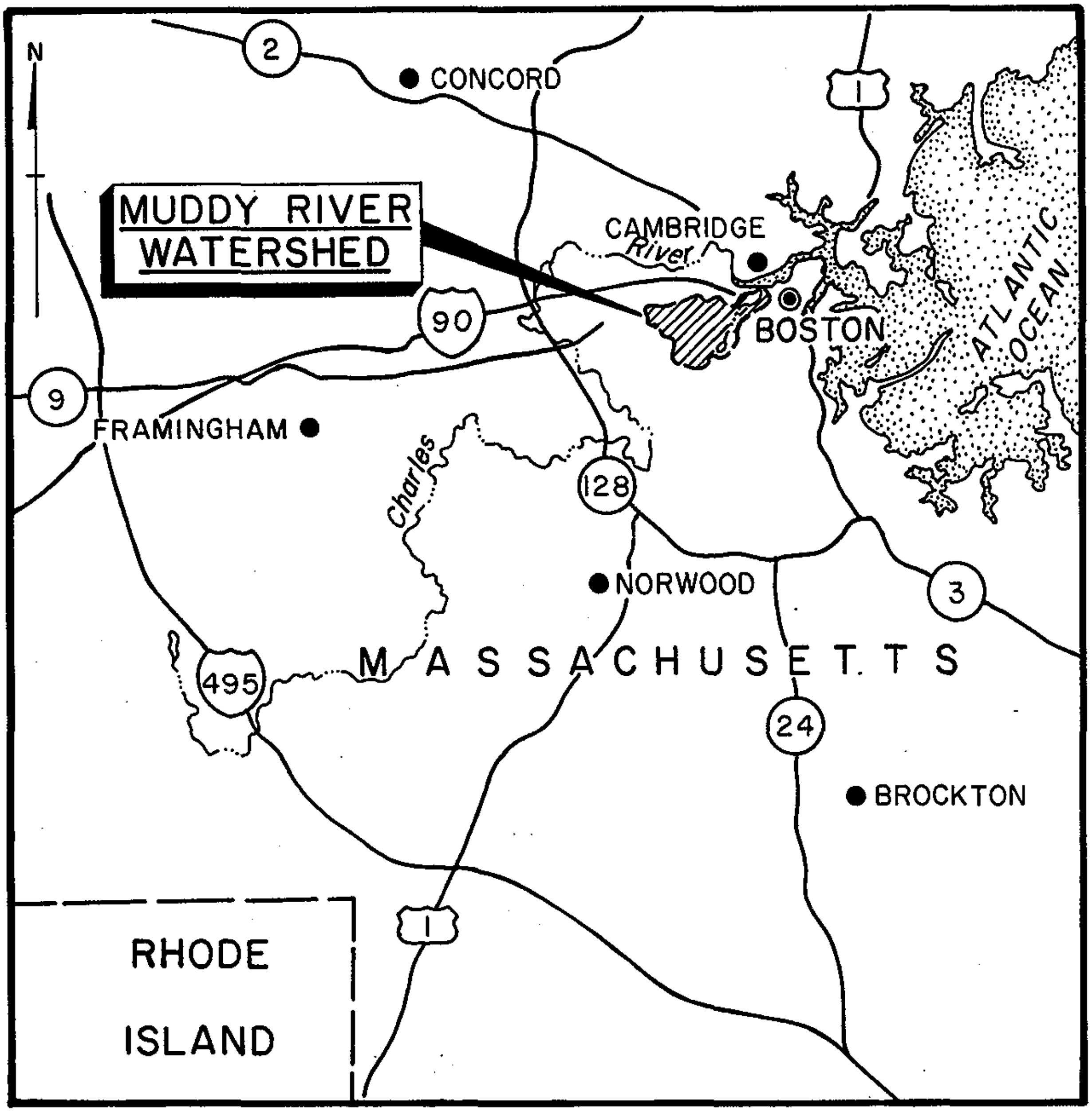
PRIOR STUDIES AND REPORTS

Land and Water Resources of the New England-New York Region - This report, completed by the New England-New York Inter-Agency Committee (NENYIAC) in March 1955, contains a comprehensive study of the overall land and water resource problems and opportunities of the region. Part Two, Chapter XVI, contains basic material on water management and water quality in the Charles River area.

Reconnaissance Report - Local Protection, Muddy River, Boston-Brookline, Massachusetts - This letter report (unpublished) was submitted to the Chief of Engineers on 21 April 1966 pursuant to authority contained in Section 205 of Public Law 87-874, adopted 23 October 1962. The report includes a description of the area, presents material on stream characteristics, and discusses the flood problems of this watershed. In view of the scope, cost and close relationship between flood stages on the Muddy and Charles Rivers, it was recommended that further investigations of the Muddy River be incorporated with the Charles River Basin Study, authorized on 24 June 1965.

Charles River Interim Report - Lower Charles River - This report, completed by the New England Division, Corps of Engineers in May 1968, recommended that a new Charles River Dam be constructed to replace the original 1910 dam, and meet the current flood control and navigation needs of the lower Charles River.

Charles River Study Report - This second planning report concerning the water resource needs of the Charles River Basin was completed by the New England Division, Corps of



MUDDY RIVER WATERSHED
LOCATION MAP

PLATE 1

Engineers in 1972. It addressed the needs of the middle and upper basin areas, and recommended acquisition of natural valley storage areas to prevent future flood damages.

Other reports or documents reviewed and/or evaluated as part of this reconnaissance study include the following:

Water Quality Improvement of The Boston Back Bay Fens, prepared by CE Maguire, Inc. for the Massachusetts Division of Water Pollution Control, May 1973.

The Charles Basin Water Quality Survey Data - 1974, Massachusetts Division of Water Pollution Control, November 1976.

Flow Augmentation of the Boston Back Bay Fens Pond, prepared by CE Maguire, Inc. for the Massachusetts Division Of Water Pollution Control, February, 1977.

Combined Sewer Overflows, Charles River Basin Facilities Planning Area, Vol. I, Engineering Report and Vol. II, Environmental Assessment, prepared by Metcalf & Eddy for the Metropolitan District Commission, June 1980.

FEMA Flood Hazard Boundary and Flood Insurance Rate Maps for the town of Brookline, November 28, 1980.

Environmental Impact Report on Control of Combined Sewer Overflows for Neponset River Estuary, Dorchester Bay, Charles River Basin, Boston Inner Harbor, prepared by Camp, Dresser & McKee, Inc. for the Metropolitan District Commission, February, 1982.

Cynthia Zaitzefsky, Frederick Law Olmsted and the Boston Park System, the Belknap Press of Harvard University Press, Cambridge, Massachusetts and London, England, 1982

Muddy River - Back Bay Fens, 1986 Water Quality Data and Water Quality Analysis, Massachusetts Division of Water Pollution Control, February 1987.

Combined Sewer Overflow Facilities Plan, Technical Memorandum B3-7, Restoration of the Fens and Phase II In-System Modifications, prepared by Whitman & Howard, Inc. for the Massachusetts Water Resources Authority, July 20, 1988.

Combined Sewer Overflow Facilities Plan, Technical Memorandum B3-1, In-System Modifications in the Charles River Basin Area, prepared by Whitman & Howard, Inc. for the Massachusetts Water Resources Authority, December 29, 1988.

Tannery Brook Storm Drain Investigation, Town of Brookline, Massachusetts, prepared by Camp, Dresser & McKee for the town of Brookline, April 1989.

Combined Sewer Overflow Facilities Plan, Technical Memorandum 7-3, Preliminary CSO Controls Using In-Line and Off-Line Storage Alternatives, prepared by PEER Consultants, P.C. for the Massachusetts Water Resources Authority, May 1, 1989.

Muddy River Water Quality Improvement Plan, prepared by Metcalf & Eddy for the Massachusetts Department of Water Pollution Control, September 28, 1990.

City of Boston Flood Insurance Study, prepared by FEMA, November 2, 1990.

1990 Muddy River Fish Toxics Monitoring Report, prepared by the Massachusetts Department of Environmental Protection, October 15, 1991.

Phase I Planning Report on Rehabilitation of the Muddy River Conduit, prepared for the Boston Water and Sewer Commission by Anderson-Nichols and Company, Inc., October 1992.

Treatment of an Urban Waterway as a Stormwater Mitigation Measure, A Demonstration Pilot Treatment Project Proposal, submitted by Dr. Frederic C. Blanc and Dr. Constantine J. Gregory, Department of Civil Engineering, Northeastern University, Boston, Massachusetts and John R. Elwood, P. E., Framingham, Massachusetts, to EPA on November 18, 1992.

Emerald Necklace Master Plan (Draft), prepared by Walmsley/Presley Joint Venture for the Massachusetts Department of Environmental Management, undated.

EXISTING WATER RESOURCES PROJECTS

In 1965 the Metropolitan District Commission completed construction of a dike and floodwall along the left bank of the Muddy River that extends from Route 9 downstream to Park Drive. The project is approximately 5800 feet long, 6 to 8 feet high and has a top elevation of about 14.3 NGVD (National Geodetic Vertical Datum). Although the dike and floodwall are somewhat effective in preventing overbank flooding, the number of drain openings and lack of interior drainage facilities compromise the effectiveness of the project.

The Corps of Engineers completed construction of the new Charles River Dam in May 1978. This project replaced an old dam that was unable to meet flood control and navigation needs and could not be economically modified. The new dam, which includes a large pumping station to discharge river flows in the event of high tide levels, provides flood protection to about 2440 acres of urban property along the banks of the Charles River. Due to much lower flood heights in the Charles River Basin, this project has also resulted in lower flood stages along the lower Muddy River, particularly in the Back Bay Fens.

ONGOING STUDIES AND INVESTIGATIONS

Although there are no other ongoing Federal studies or investigations in the watershed, the U.S. Environmental Protection Agency (EPA) continues to monitor the water quality of the Muddy River.

REPORT AND STUDY PROCESS

This reconnaissance study is the first phase of a two phase planning process that provides a mechanism to accommodate significant non-Federal participation in Corps planning studies. The reconnaissance phase provides a preliminary indication of the potential of the study to yield solutions which could be recommended to the Congress as Federal projects. It also provides the basis for decision-making within and outside the Corps and the Administration to evaluate the merits of continuing the study and allocating feasibility (second) phase funds. This reconnaissance study has accomplished the following:

a. Defined the water and related land resources problems and opportunities of the study area.

b. Developed the objectives and constraints of the study based on identified needs and opportunities.

c. Identified measures to address these needs and opportunities.

d. Developed alternative plans to meet these problems and opportunities.

e. Conducted a preliminary evaluation and screening of alternative plans, to include a preliminary determination of likely impacts and non-Federal views and preferences.

g. Assessed the level of interest in and support for identified potential solutions, and obtained concurrence from the non-Federal sponsor of their understanding of cost sharing requirements.

h. Determined whether planning should proceed into the feasibility phase based on a preliminary appraisal of consistency with current policies and budgetary priorities. This appraisal considered costs, benefits, impacts and support for identified potential solutions.

i. Assessed existing and expected future conditions and determined whether the Muddy River met the flow criteria required for Corps of Engineers participation in flood damage reduction.

The following four basic planning tasks of problem identification, formulation of alternatives, impact assessment and evaluation were conducted during evaluation of flood damage reduction measures. However, since the Corps of Engineers has no authority to implement single purpose environmental improvement plans, study of environmental needs was limited to defining the problem and identifying potential management measures.

Problem Identification - This task served to identify the flooding and related water resource problems to be addressed and to establish study planning objectives. This included the development of a regional profile of environmental, social and economic conditions for the study area. The study objectives guided formulation of alternatives, whereas the regional profile served as a base condition for determining impact assessment and evaluating capabilities of alternatives.

Formulation of Alternatives - Formulation involved the process of developing alternative flood plain management systems which responded to identified problems and concerns, and the study area planning objectives. All potential measures available for problem solution were identified, and both structural and nonstructural measures were considered in developed plans.

Impact Assessment - This function included tasks required to determine the effect of each alternative plan on existing social, economic and environmental conditions. These effects were measured over the impact zone.

Evaluation - The evaluation function involved work tasks needed to measure and compare the relative values of each alternative plan, particularly in response to achieving the study objectives. Benefits and losses associated with the development of each plan were described in order to effectively analyze possible trade-offs between plans and to recommend further study or action.

SECTION II

PLANNING SETTING

WATERSHED DESCRIPTION

The Muddy River has a total watershed area of 8.6 square miles. About 65 percent of the basin is situated in the town of Brookline, 25 percent is located in the City of Boston and less than 10 percent is in the City of Newton (see Plate 2). Brookline, which has a population density of over 8,000 people per square mile, is typical of the dense development of the watershed. As expected in this type of urban area, the majority of runoff from the watershed is conveyed to the river via storm drains that follow old streambeds.

The Muddy River, shown on Plate 3, originates at the outlet of Jamaica Pond and follows a general northeasterly course for about 3.5 miles to its confluence with the Charles River within the Charles River Basin. A major feature of the river is that it flows through a series of parks for almost its entire length. This park system was crafted by the famous landscape architect, Frederick Law Olmsted, in the late 1800's. The river also forms the border between Boston and Brookline for about half of its length.

As shown on Plate 3, the river is very steep and fast flowing in its upper reaches, but becomes extremely flat and sluggish for most of its length. Most of the river's fall (about 49 ft) occurs in the first half mile from Jamaica Pond to Willow Pond. The lower portion of the river from Leverett Pond to its mouth is very flat, falling less than a foot per mile.

The river has seven major storm drain outlets along its length. These drains, shown on Plate 4, include the Chestnut Street drain that enters Willow Pond, the Daisy Field and Village Brook drains that enter Leverett Pond, and the Huntington Avenue, Tannery Brook, Longwood Avenue and Emmanuel College drains that enter the main stem of the river. These drains represent nearly 90 percent of the river's drainage area. Another important feature of the watershed is the Muddy River Diversion Conduit. This conduit, shown on Plate 4, was originally designed to convey heavily polluted Muddy River flows directly to the Charles River. When originally constructed in 1883, gates within the Brookline Avenue Gate House were used to divert normal flows to the conduit. During times of high river flows, these gates were opened and excess flows would be discharged through the Back Bay Fens. All of these gates have been removed, and the gate house presently serves to split flows between the conduit and Back Bay Fens section of the Muddy River.

In addition to the Muddy River Conduit there are several other segments of underground culverts located in the vicinity of the gate house. These culverts, shown on Figure 1, connect the Riverway and Back Bay Fens sections of the Muddy River. Initially flow enters two 6 foot diameter culverts that are located under the former Sears Parking lot and lead to the gate house. Flow that continues to the Back Bay Fens enters a 7 foot by 9 foot conduit that passes under Brookline Avenue. This conduit is connected to another section of twin 6 foot diameter culverts that discharge into a small pond adjacent to Emmanuel College. The final connection to the Back Bay Fens is via a third section of twin 6 foot diameter culverts. All sections of twin 6 foot diameter culverts were added after completion of the original park system and were installed in areas that were formerly open channel.

CLIMATOLOGY

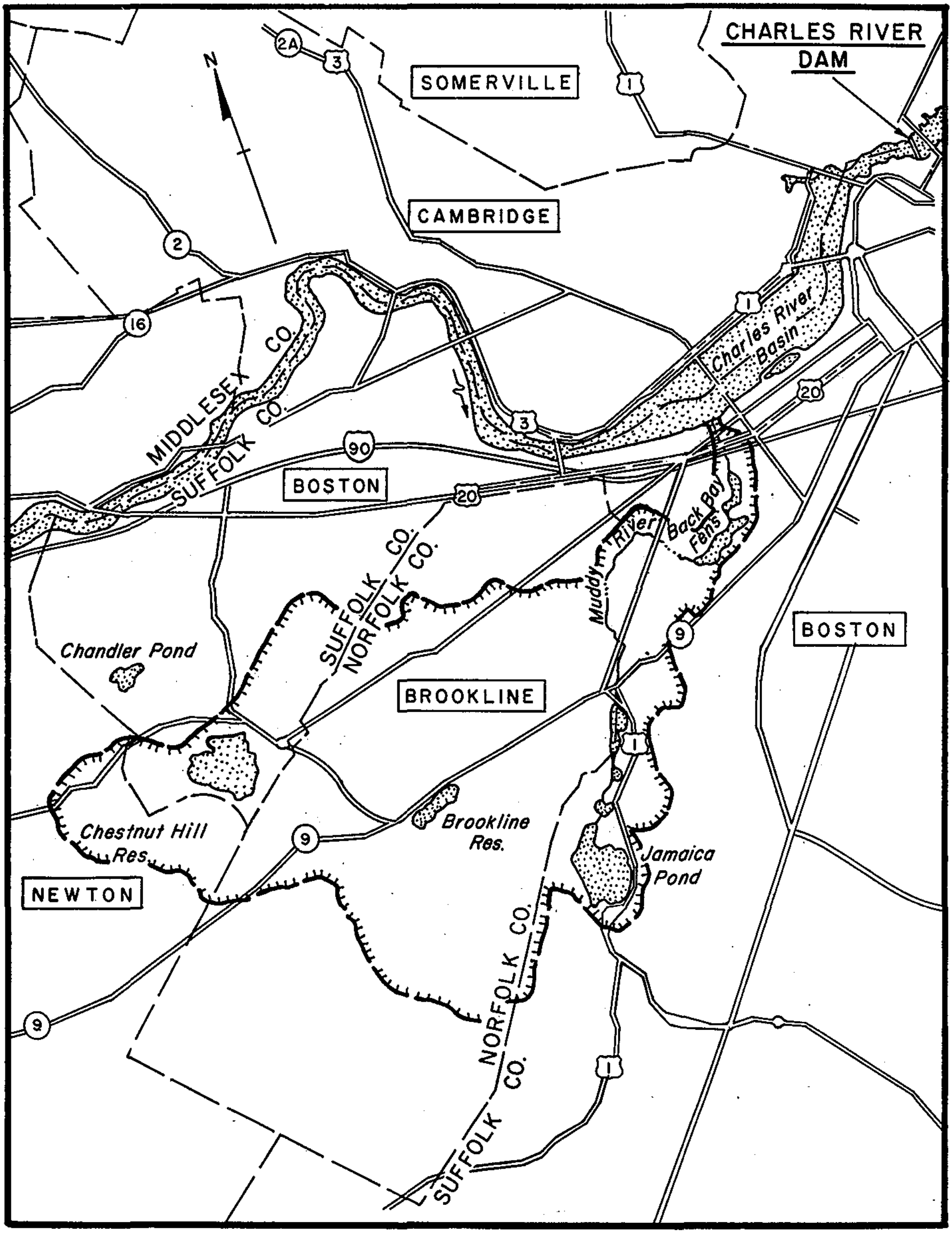
The Muddy River watershed has a variable climate characterized by a wide range of temperature and frequent but usually short periods of precipitation. The watershed lies in the path of the "prevailing westerlies" and air masses move over it primarily from the interior. The area is also exposed to coastal storms of tropical origin; that is, hurricanes that travel up the Atlantic seaboard as well as storms of extratropical origin known locally as "northeasters".

The watershed's mean annual temperature is about 50 degrees F. The range of mean monthly temperatures is wide, from the mid 70's in July to the mid 20's during January and February. Temperature extremes in the area range from a maximum of 102 degrees F. to a minimum of -21 degrees F. Average annual precipitation in Boston is 42 inches distributed uniformly throughout the year. Much of the winter precipitation is in the form of snow. The mean annual snowfall at Boston is 40 inches. Additional information concerning precipitation and temperature variations for the watershed area is presented in Appendix B.

TOPOGRAPHY AND GEOLOGY

The Muddy River watershed lies within the major physiographic province known as the Appalachian Highlands, a region typically characterized by ranges of mountains and hills composed of ancient igneous and metamorphic rock types. These mountain ranges have been exposed at the surface for a long period of time, experiencing substantial erosion, and have gently rounded profiles as a result. Topography in the study area, however, is primarily controlled by three factors: bedrock lithology and structure; the levelling effects of glaciation; and backfilling by man.

The Muddy River study area is located within the Boston basin, a structurally downthrown block bounded by faults to the north and south. The youngest rock, in the center of the watershed and underlying the study area, consists of clastic and volcaniclastic sedimentary rock types of late Precambrian to late Cambrian age, belonging to the Boston Bay Group. The sedimentary rocks are generally weaker and more easily eroded than the surrounding igneous and metamorphic rocks and therefore, as a result of preferential erosion, the Boston basin is also a topographic low.



MUDDY RIVER WATERSHED MAP

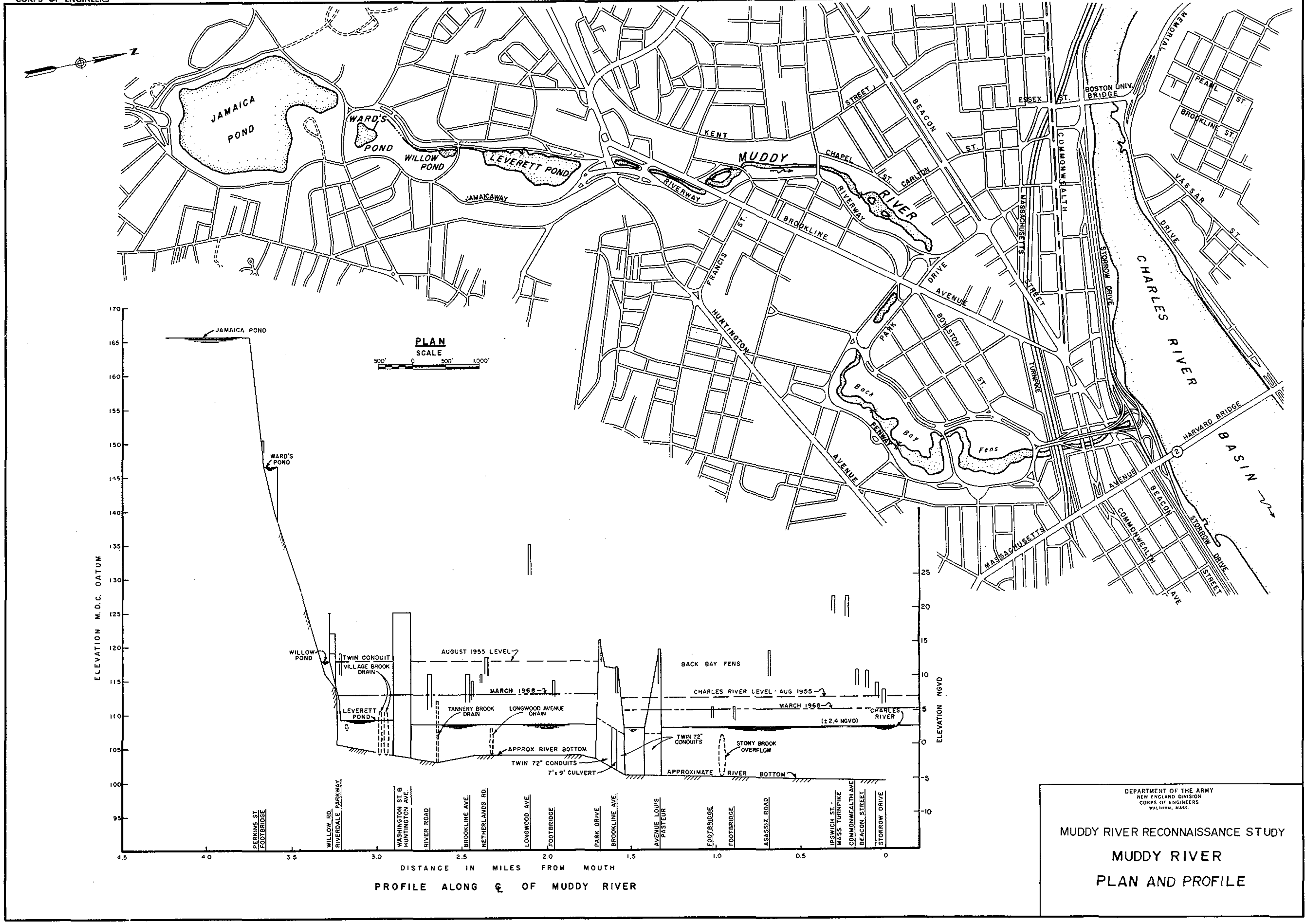
SCALE IN MILES

1 0 1

PLATE 2

CORPS OF ENGINEERS

U. S. ARMY



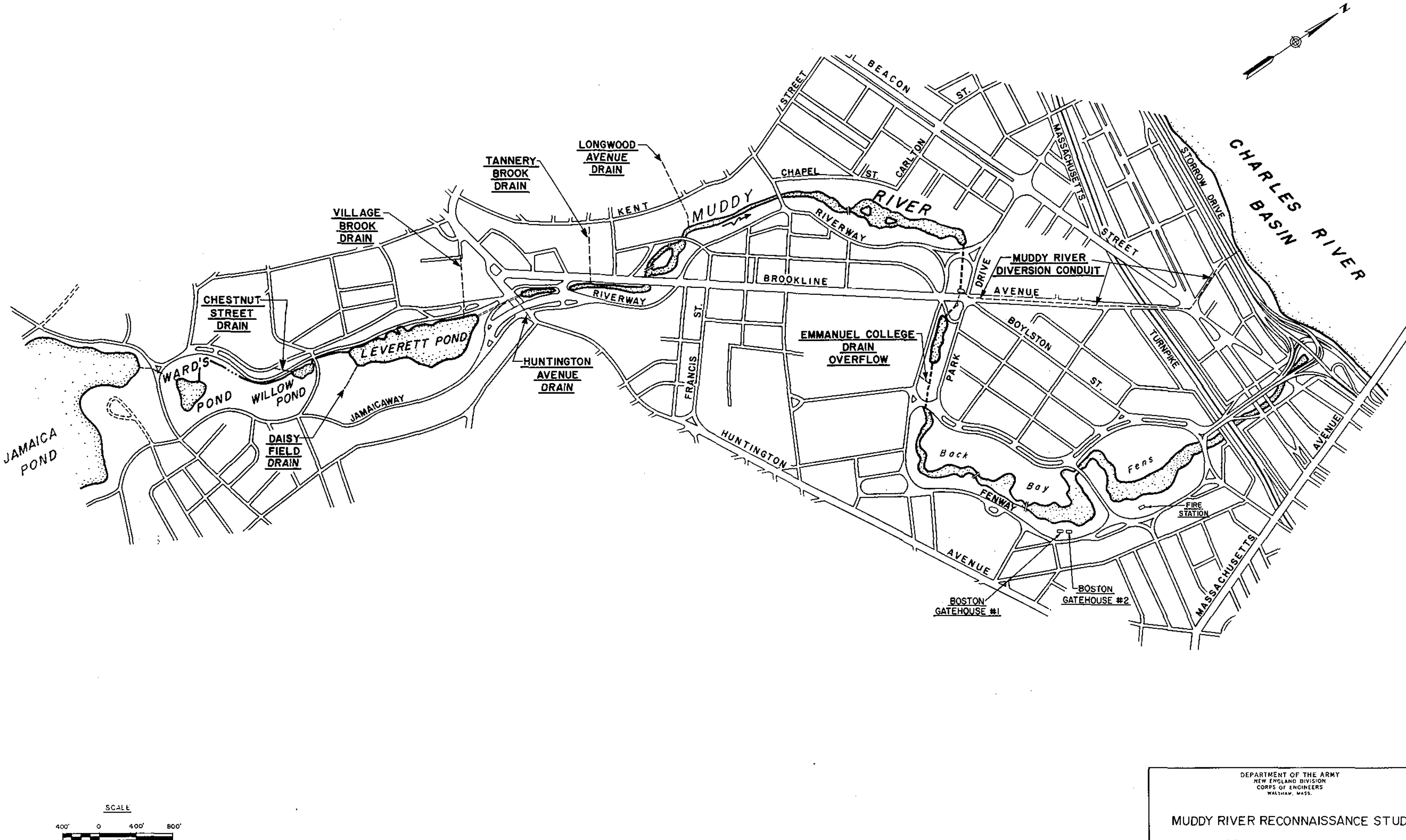
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER RECONNAISSANCE STUDY

MUDDY RIVER

PLAN AND PROFILE

PLATE 3



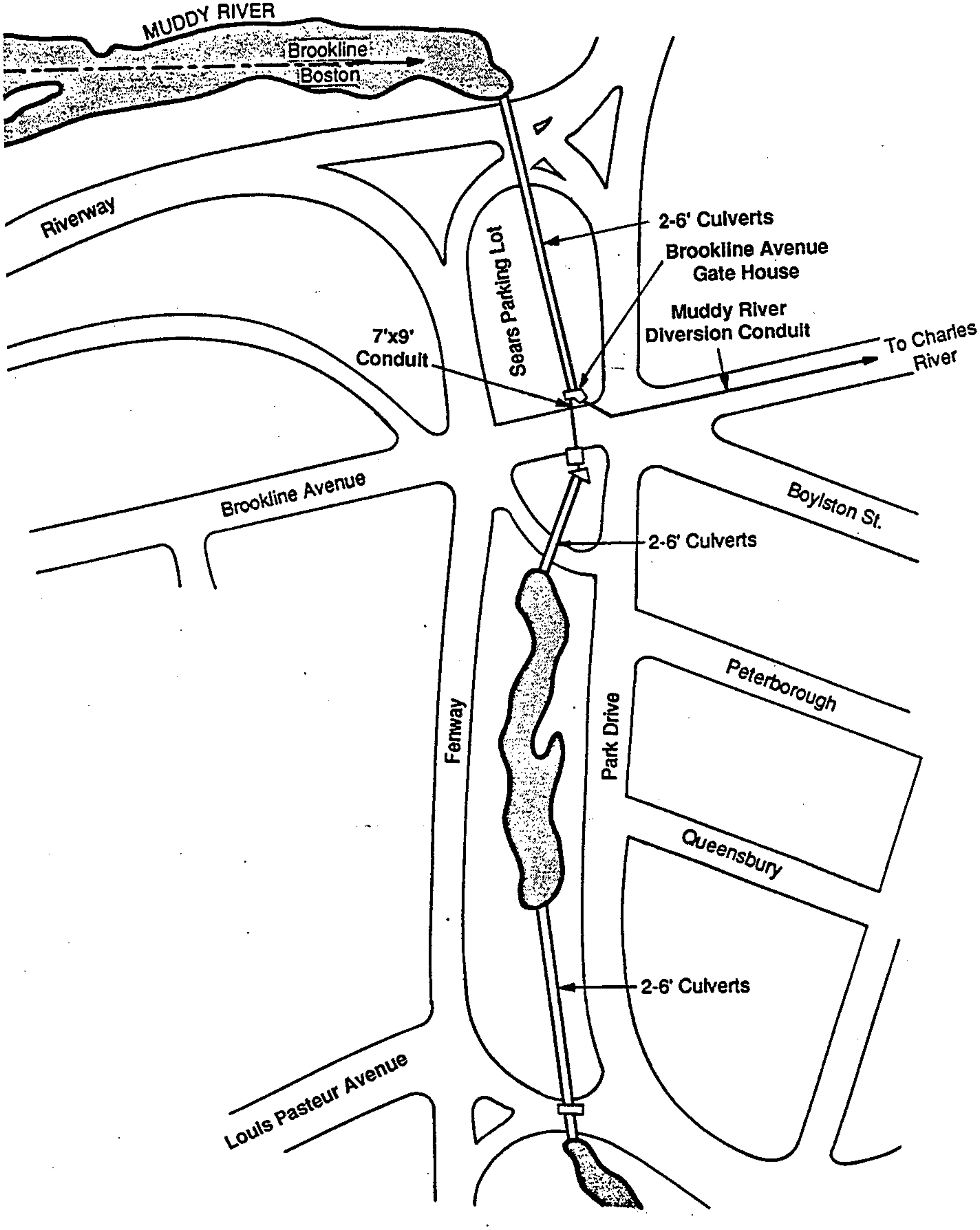
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER RECONNAISSANCE STUDY

MUDDY RIVER

DETAILED VICINITY MAP

PLATE 4



Underground Culvert System Connecting
the Riverway to the Back Bay Fens

Figure 1

The primary bedrock units underlying the study area are the Roxbury Conglomerate and the Cambridge Argillite. The Cambridge Argillite is gray, laminated, silty to clayey in texture, weakly metamorphosed, and may contain a significant volcanic tuff component. The Roxbury Conglomerate is generally lower than the argillite stratigraphically, but also interfingers with it in places. In addition, a system of faults in the study area further complicates the relationship between these units. Bedrock should not have a significant impact on the study, as it is generally at least 50 feet below the ground surface along the river channel, and may be as deep as 250 feet where the river crosses an old buried valley. Bedrock outcrops are, however, exposed on some of the hills within the watershed.

The effects of the last glaciation had a great impact on topography within the Boston basin. Generally, the glaciers blanketed the existing bedrock topography with drift deposits, filling in bedrock valleys and leaving a complex assortment of deposits. These range from poorly sorted sandy and gravelly till, and plastic, glaciomarine clays; to stratified, well sorted sand and gravel outwash deposits. At the end of the last glacial period, there was a resultant rise in sea level, which created large expanses of tidal flats in the widened river estuaries, where organic silt and peat were deposited.

The Muddy River is a gently meandering stream, with gently sloping banks, flowing through a narrow parkway. The meandering course of the stream was originally the result of flowing over the relatively flat-lying glacial drift deposits. The rise in sea level at the end of the last glaciation drowned the lower portion of the valley, creating a much wider mouth at the confluence of the Muddy River with the Charles River. The backfilling of this tidal flat area by man has shaped the present course of the Muddy River.

Historic boring data available for areas adjacent to the Muddy River show varying thicknesses of fill overlying variable deposits of peak, organic silt, and silty fine sand which overlie clay. Consistent with the geologic setting of this area, the fill and organic silt/peat units are generally thicker as the boring locations move downstream toward the Charles River.

Topography in the study area is relatively flat to gently rolling, with elevations generally less than 50 feet NGVD (see Plate B-1). Parker Hill, located southwest of the Harvard Medical School, is an example of a typical glacially-formed drumlin with a bedrock core, created by glacial ice smearing debris over and around a protruding rock knob. Conglomerate bedrock outcrops in places on this hill. Reaching an elevation of approximately 200 feet NGVD, Parker Hill is among the highest points along the Muddy River.

HISTORIC AND ARCHAEOLOGICAL RESOURCES

The study area includes a portion of the Olmsted Park System which was accepted for inclusion on the National Register of Historic Places on 8 December 1971, as a National Register District. The Olmsted Park System includes a series of parks linked by continuous parkways. It curves south from the mouth of the Muddy River to Franklin Park. When originally conceived, the System also included Boston's existing parks, the Common and the Public Garden, which were linked to the Olmsted Plan by the Commonwealth Avenue mall. This historically significant area is composed of six properties: the Back Bay Fens, the Riverway, Olmsted (Leverett) Park, Jamaica Park, the Arnold Arboretum, and Franklin Park. All areas, except the Arnold Arboretum and Franklin Park, are located in the study area and constitute the vast majority of land adjacent to the river.

This comprehensive park system, which Frederick Law Olmsted Sr. planned for the City of Boston and town of Brookline in the late 1870's, is one of the Nation's best examples of the multiple-use of open space, and the landscape architect's finest design project in New England. Olmsted's work on the system, which became known as the "Emerald Necklace" around Boston, created a strong precedent, for it included all the design and planning elements that later landscape architects applied to regional planning on a large scale.

Olmsted's original plans for the park system had three purposes: to create needed municipal open space while solving an engineering problem; to link newly annexed parts of the city with its historic center; and to provide, as in his earlier designs for New York City's Central Park (1857-63), a variety of forms of recreation. Olmsted established a hierarchy of uses for areas within the system, creating large and medium sized parks for rural relaxation and picnicking, smaller landscaped areas with ponds for recreation, and linear parkland for pleasure driving, riding, and hiking.

The Back Bay Fens and the Fenway were the first portions of the park system to be planned. In the 1870's, the Fens area was a tidal wetland that received sewage from both the Muddy River and Stoney Brook. The area was also subject to violent flooding. The three-man Boston Park Commission was created in 1875 primarily to find a solution to these problems. Following unsuccessful competition for a design, Olmsted was asked to prepare a new plan for the Fens. Using vegetation able to withstand periodic inundation with salt water, he created an informal park which was a unique feat of engineering skill and naturalistic landscaping.

The Muddy River Improvement, which includes both the Riverway and Olmsted Park, and Jamaica Park were the last sections of the "Emerald Necklace" to be constructed. The Muddy River Improvement was not part of the commissioners' original plan; instead it was suggested by Olmsted to improve the banks of the Muddy River in both Boston and Brookline. Like the Fens, the Muddy River Improvement is largely man-made. However, his naturalistic landscaping was so successful that people consider this area a piece of wild land "left over" after development.

WATER QUALITY

Water quality in the Muddy River varies greatly between its source at Jamaica Pond and its downstream reaches; the Riverway and Back Bay Fens areas. Although the river is currently classified as Class B by the Massachusetts Division of Water Pollution Control (MA DWPC), it generally fails to meet these criteria throughout its entire length, except at

Jamaica Pond, which normally meets these criteria. This classification was established in 1990 as a goal for the waterway. Class B waters are considered acceptable for bathing and other recreational purposes; protection and propagation of fish, other aquatic life and wildlife; and after appropriate treatment, for use as water supplies. Massachusetts Class B classification criteria is included in Appendix C, Table 3.

The water quality of the Muddy River has historically been poor. Many projects, including construction of the Riverway section of the "Emerald Necklace" and Muddy River Conduit, were designed to mitigate the impacts of urban pollution on the river. The water quality has been improved over the years by eliminating combined sewer overflows and other actions, but high fecal coliform counts, low dissolved oxygen levels and high nutrient levels (causing excessive algae growth) still exist along most of the river. Information concerning water quality is presented in Appendix C. Water quality is generally impacted by the extensive storm drainage system that conveys large volumes of sediment, oil from accidental spills, and other urban wastes to the river.

BIOLOGICAL RESOURCES

The Muddy River currently supports a limited warmwater fishery due to poor water and habitat quality. Carp, a species tolerant of very poor water quality conditions is predominant in both the Back Bay Fens and Riverway. Large carp were frequently seen near bridges in both the Fens and Riverway during this study. Other species known to occur in the river include brown bullhead, goldfish, golden shiner, sunfish, largemouth bass and American eel. Aquatic invertebrate communities in the Muddy River are composed largely of species tolerant of poor water quality conditions.

Fish sampled from the Muddy River and Back Bay Fens in 1990 contained high levels of PCBs. Seven of the 14 fish analyzed had PCB levels which met or exceeded the USDA action level of 2 ppm (maximum concentration was 3.4 ppm). Based on this information, a public health advisory was issued recommending that people not consume carp, brown bullhead, or American eel from the Muddy River and limit consumption of other species to two meals per month. Concentrations of metals in fish were low, and did not exceed FDA action levels.

Jamaica Pond supports a good warmwater fishery, with healthy populations of large mouth bass, yellow perch, bluegill, pumpkinseed, white crappie, pickerel, and bullhead. The lake is also stocked on a put and take basis with rainbow trout, and sometimes brown and brook trout.

Extensive mats of filamentous algae are present in the the Back Bay Fens during summer months. Those observed during this study were formed by blue green algae. The mats develop on sediments in shallow water areas and float to the surface. The mats are unsightly, produce noxious odors upon decomposition, and limit recreational use of the water. Corps water quality sampling found moderately high counts of planktonic algae (primarily diatoms and greens) in both the Riverway and Back Bay Fens in June of 1992, but low levels by August (see Appendix C).

Extensive Phragmites stands are present in the Riverway and the Back Bay Fens (see Appendix F). In the Riverway, Phragmites currently occupies about 2 acres, and grows along 30 percent of the shoreline. In the Fens, Phragmites development is most extensive in the Northern and Southern Basins where a total of 5.3 acres is present. Phragmites occurs along about 90 percent of the Northern Basin shoreline and 50 percent of the Southern Basin shoreline. Phragmites growth in the Muddy River is robust. In well established stands shoots frequently exceed 5 meters in height, and range up to nearly 7 meters. In shallow water, these stands are expanding laterally several meters per year.

A few small cattail stands are also present in the Muddy River. The largest of these are in the Riverway near Park Drive, and in the Upper and Lower Fens Basins near the Agassiz Bridge.

A narrow fringe of emergent vegetation occurs along the shore throughout the Riverway and Back Bay Fens in locations that are not colonized by Phragmites or heavily shaded by riparian vegetation. A few freshwater herbaceous wetland plants were included in Olmstead's original plantings in the Muddy River, but three of the most common emergents in the Muddy River today, Phragmites, cattails, and loosestrife, were apparently not planted. Plant communities along the Muddy River originate from plantings made in the 1890's during construction of the Emerald Necklace parks. Plans called for planting a great variety of trees, shrubs, and herbaceous species.

Riparian vegetation is currently well developed along much of the Riverway section of the Muddy River and the Upper Fens Pond. In the Riverway, tree and shrub cover is heavy along most of the Brookline side of the river from the Leverett Pond outlet to Park Drive. Vegetation is less well developed along much of the Boston side of the river, where turf is maintained nearly to the river's edge. A list of common species noted along the Riverway is presented in Appendix E, Table E-1.

Riparian vegetation is much less well developed along the Back Bay Fens section of the Muddy River downstream of the Upper Fens Pond. Shoreline vegetation is limited to shrubs and scattered trees. Turf extends to the shoreline (or edge of Phragmites) in most locations. Away from the river, most of the Back Bay Fens park land is turf.

The Muddy River and associated riparian vegetation, marshes, and open space provide habitat for a great variety of mammals, birds, and reptiles. The area supports resident populations of many species and provides a refuge for songbirds and waterfowl migrating through the Boston area. A list of birds likely to nest or commonly occur in the Riverway and/or Back Bay Fens is presented in Appendix E, Table E-2. Semi-domesticated mallards are very abundant in both the Riverway and Back Bay Fens throughout the year. Mammals known or likely to occur in the project area include gray squirrel, raccoon, striped skunk, opossum, muskrat, Norway rat, big brown bat, mice, voles, and shrews. Reptiles and amphibians reported to occur in the project area include painted turtle, snapping turtle, bull frog, red eared turtle, and American toad. Others reported from the Olmstead Park area which may also occur in the Riverway or Fenway include spotted turtle, stinkpot turtle, eastern garter snake, DeKay' snake, red-backed salamander, dusky salamander, green frog, and leopard frog.

THREATENED AND ENDANGERED SPECIES

No federally listed threatened or endangered species are known to occur in the project area. A rare fish, the threespine stickleback (Gasterosteus aculeatus), is known to occur in a small spring-fed pool which drains into Willow Pond. The species is state-listed as threatened, and the population is the only one known to occur in Massachusetts. Spotted turtle, a state listed special concern species, is known to occur in the Olmstead Park area.

SECTION III

PROBLEM IDENTIFICATION

Water resources related problems were identified in a number of ways. First, with study initiation, letters were sent to Congressional interests and other government agencies that traditionally have an interest in Corps planning studies. Based on this and other contacts with government officials, an Inter-Agency Working Group was formed to insure close coordination between Federal, State and local interests. Second, in addition to reviewing past Corps of Engineers reports, many reports and studies prepared for other agencies having responsibilities in the study area were reviewed. Third, numerous visits were made to the watershed to study the area and discuss problems and concerns with government officials and individual citizens. As a result of these efforts, the following problems were identified:

Flood Damages
Water Quality
Sediment Quality and Quantity
Phragmites Expansion
Fisheries Degradation
Recreation

A brief discussion of each of these problems is presented in the following paragraphs.

FLOOD DAMAGE

The Muddy River has had a long history of flooding, particularly in the Back Bay Fens area and along the left bank of the Riverway section of the river. Floods can occur during any time of the year due to extensive development in the watershed, the flat stream gradient and locally restrictive conduits and channels. Major recent floods occurred in August 1955, October 1962 and March 1968. Information concerning these floods is presented below.

August 1955 Flood.

The flood of 18-19 August 1955 is the flood of record on the Muddy River. This flood was caused by a storm that followed hurricane "Diane". During this event, high intensity rainfall, totaling about 12.7 inches, fell in the Boston area. Based on an analysis of the watershed, this flood is considered to be a 100-year event. This flood caused damge throughout the watershed, including flooding at Brookline Village, the Back Bay Fens area and adjacent to the river in the vicinity of Storrow Drive.

October 1962 Flood.

This flood was caused by a high intensity coastal storm on 5-6 October 1962. Approximately 8.5 inches of rain fell in the Boston area causing overbank flooding along much of the river. The most hard hit area was the Brookline side of the river upstream from the Muddy River Diversion Conduit. Undersized culverts in this area caused overbank flooding and subsequent inundation of the Boston underground transit system at Kenmore Square.

March 1968 Flood.

This flood, less severe than the events previously discussed, was the result of 4.8 inches of rain falling on saturated ground. The majority of flooding occurred in the lower watershed on 17-18 March and was most likely the result of backwater effects from the Charles River Basin. The basin rose 2.85 feet above normal and inundated sections of Storrow Drive. This flood is estimated to be a 10-year event.

Analysis of Floods.

To determine the flood potential of the watershed and to identify sub-watershed areas with the greatest impact on flooding, the three most recent floods of record (1955, 1962 and 1968) were analyzed. A simulated 2-year frequency storm was also developed and flood hydrographs developed for each sub-catchment area. Two computer models were used to evaluate flooding conditions on the Muddy River. To compute the contributing runoff from the different sub-catchment areas in the upper watershed, the Storm Water Management Model (SWMM) was used. This model was used because the area upstream of Park Drive acts like a reservoir with flood stages being a function of runoff volume and the limited discharge capacity of the twin 6 foot diameter culverts under the former Sears parking lot. In the lower portion of the river (through the Back Bay Fens), the HEC-2 computer program was used to develop water surface profiles based on inflows to this area.

This analysis determined that flooding along the Muddy River is caused by the flat stream gradient, restrictive culverts (particularly at Park Drive) and insufficient channel size in some reaches. The dike and floodwall along the left bank of the river, which has limited interior drainage facilities, also affects flood potential.

Existing Flood Control Projects.

As mentioned earlier, there are two flood control projects located in the general study area. The Corps-constructed Charles River Dam, which is operated and maintained by the Metropolitan District Commission (MDC), has resulted in a substantial reduction in flood levels along the lower Muddy River, particularly in the Back Bay Fens area, since its completion in 1978. The dikes and floodwalls, constructed by the MDC and situated along the Brookline side of the Riverway, reduce overbank flooding along this section of river.

Flood Damages.

To determine potential future flood losses, floodplain areas in Brookline and Boston were divided into three damage zones. These areas were designated as follows:

ZONE	AREA
1	Upstream of Park Drive
2	Vicinity of the Louis Pasteur Bridge
3	Vicinity of the Agassiz Bridge

Flood Damage Survey - A flood damage survey of areas in Brookline and Boston was conducted in June 1992. Flood related losses were estimated for each floodprone structure from the elevation at which discernible losses and damages would first occur up to an elevation 3 feet above the 1955 flood event. First floor and ground elevations at each building were estimated from spot elevations on topographical mapping. Dollar value estimates of potential damages to sites, structures, contents and utilities were developed. The damage evaluators conducted interviews with occupants and local officials concerning potential or historic flood losses to commercial, industrial and public structures. For residential properties, structures were categorized by type and typical loss profiles were utilized to estimate damages. Minimal interviewing was conducted for residential surveys.

Recurring and Annual Flood Losses - Recurring losses are the potential flood related losses which are expected to occur at various stages of flooding. Under present day development conditions, a recurrence of the 1955 flood (100-year event) could cause an estimated $2.7 million in damages to residential, commercial and public structures upstream of Park Drive, and $0.3 million in damages in the vicinity of the Agassiz Bridge. There would be no damages in Zone 2. Damages in this zone would not start until elevation 11 feet NGVD which is above the 100-year event. Total recurring losses for selected events in the three damage zones are shown in Table 1.

TABLE 1
RECURRING LOSSES ($1,000)

Zone	10-year	50-year	100-year
1	0	0	2,700
2	0	0	0
3	0	300	300
TOTAL	0	300	3,000

To measure the severity of potential flooding, annual losses for the same damage zones were also estimated on an expected annual basis. Annual losses are the integration and summation of two sets of data at each

damage location. Recurring losses for each flood elevation (event) are multiplied by the annual percent chance of occurrence of that event. The resultant annual loss figure represents the average annual damage that can be expected in each zone. Table 2 summarizes annual losses at these zones.

TABLE 2
ANNUAL LOSSES

Zone	Annual Losses
1	$35,000
2	0
3	6,000
Total	$41,000

ENVIRONMENTAL PROBLEMS

Water Quality.

In general, current water quality problems in the Muddy River are similar to those of many older highly urbanized river basins found in some of the larger cities of the United States. The river, although currently classified as Class B by the Massachusetts Division of Water Pollution Control (MA DWPC), fails to meet these criteria generally throughout its entire length, as a result of high incoming pollutant loads, low assimilative capacity, and unique sluggish hydraulic characteristics of the Back Bay Fens.

Pollutant sources to the Muddy River include: sewer cross connections from several of its major catchment areas, combined sewer overflows, a periodically overflowing sewer siphon, an historically leaking skating rink refrigeration system, accidental oil spills, and urban storm drainage discharges.

A Corps of Engineers water quality sampling program was performed during dry and wet weather periods during the 1992 summer, to provide an update on conditions. In addition, a sediment sampling program, which is described in detail in the following Sections and Appendix D, was undertaken concurrently to determine disposal requirements for any proposed channel improvement or dredging project and to allow definition of sediment/ water quality factors.

The most significant problems identified in this investigation and during previous sampling by the State and others (see Appendices C and D) included very high fecal coliform exceedances, generally existing along the entire length of the river below Jamaica Pond; followed in order by: (a) low dissolved oxygen (DO) levels which occur regularly below the Route 9 bridge, (b) high nutrient levels and associated excessive algae growth

problems (significant variations in pH, DO, turbidity, etc.), (c) high organic, metals, and trash releases from storm drain discharges, (d) releases of heavy metals, organic acids and gasses from bottom sludges after DO has been depleted, and (e) occasional accidental oil spills throughout the entire stream length.

In addition, concentrated metals found in sediment samples are expected to leach out into the water column whenever the DO is depleted as a result of biodegradation. This would create a constant source of pollutants during the warm summer months. The most consistent metal problems were lead, copper, arsenic, zinc, and mercury. Appendix C contains additional information concerning the potential impact that these sediments would have on water quality.

Sediment Quality and Quantity.

The accumulation of sediments has been an historic problem along the Muddy River, particularly since the construction of the Charles River Dam in 1910. This dam effectively eliminated tidal flushing in the lower basin and causes backwater effects that are felt upstream to the Riverway section of the river. Accumulated sediments were removed from the Riverway in the 1930's and again in the early 1960's. In addition, during the spring and summer of 1976, the Commonwealth of Massachusetts removed between 10,000 and 15,000 cubic yards of sediment from the Back Bay Fens as a research and demonstration project.

To evaluate the current quality of sediments in the river and determine potential disposal requirements, the Corps of Engineers collected fifteen sediment samples from the Riverway and Back Bay Fens sections of the river in June 1992. All samples were tested for regulated metals, petroleum hydrocarbons and grain size. In addition, six representative samples were tested for PCBs (polychlorinated biphenyls), and four samples were tested for volatile and semivolatile organics and TCLP (Toxic Contaminant Leaching Procedure) metals. These tests determined that nearly all samples contained highly elevated metal levels. Most samples had elevated levels of lead, mercury, copper and zinc. Total petroleum hydrocarbon levels were also high, averaging 3440 parts per million (ppm). As with metals, urban runoff is likely the major cause of this pollution. PCB levels, ranging from 0.3 to 3.6 ppm, were moderately elevated, but well below levels which have been reported for other heavily polluted riverine areas such as along the Millers and Housatonic Rivers. A variety of polyaromatic hydrocarbons, and other semi-volatile and volatile organics were detected in sediments near major outlets. These are probably largely derived from engine exhaust, and reach the river in urban runoff. TCLP metal levels were below regulatory limits for all samples. A more extensive discussion of the results of this sampling program is presented in Appendix D.

Sediments within the Back Bay Fens area have been the subject of several studies and reports. Most of these reports agree that as much as 150,000 cubic yards of sediment is present in this area and it is as deep as 12 feet below the normal water level. One of the more recent reports (1988), prepared for the Massachusetts Water Resources Authority by Whitman & Howard, Inc., estimates that partial dredging of the Fens to a depth of three feet would require the removal of 20,000 cubic yards of sediment.
River cross section information obtained as part of this study indicated that between one and two feet of sediment has accumulated in the Riverway section of the river since the last dredging in the 1960's. The most serious deposition has occurred in the area upstream of Netherlands Road, where sediments have almost totally blocked the eastern channel around Riverway Island. Large amounts of sediment have also accumulated at the northern end of Leverett Pond near the Village Brook outlet. Based on an average stream width of 50 feet and a length of about 6,500 feet, it is estimated that between 12,000 and 24,000 cubic yards of sediment would need to be removed to restore the river to conditions similar to those after the last dredging.

Phragmites Expansion.

A discussion of Phragmites distribution and expansion in both the Riverway and Back Bay Fens areas of the river is presented in the following sections.

Riverway - Aerial photographs indicate that little or no Phragmites was present in the Muddy River in 1966 (about two years after it was last dredged). By 1977, 12 distinct stands with a total area of about 0.75 acre were present. The largest stands were near Park Avenue, downstream of Brookline Avenue, and downstream of Longwood Avenue. Since 1977, both the number and size of stands has increased. Phragmites currently occurs along approximately 30 percent of the river shoreline and occupies about 2 acres (or 20 percent) of the river surface. Seventeen distinct stands, ranging in size from about 100 square feet to 0.60 acre are present. Growth is most extensive near Park Avenue, Brookline Avenue, and downstream of Washington Street. Most of the largest stands currently present were well established by 1977. See Plate F-1 in Appendix F for the location of present Phragmites stands.

Conditions are favorable for continued rapid expansion of Phragmites throughout much of the Muddy River. Shallow water, lack of heavy shading, nutrient rich sediments, slow current, and low salinity provide near optimal conditions for Phragmites growth. Assuming that no control measures are implemented, Phragmites could occupy more than half of the river surface (more than 4 acres) and at least 75 percent of the river shoreline within 10-20 years. In most of the river, water depth is currently shallow enough, or likely to shoal sufficiently in the future, to allow Phragmites growth across the entire river.

Back Bay Fens - Olmstead designed the Back Bay Fens to be brackish, and it was originally planted with saltmarsh vegetation. Phragmites probably did not occur in the Fens until after 1910 when completion of the old Charles River Dam greatly reduced salinity. Aerial photographs show that Phragmites was well established in the Northern Basin by 1951, occurring along about one-third of the shoreline and occupying about 0.3 acre. Only small isolated stands were present in the Southern Basin, or elsewhere in the Fens. By 1977, Phragmites occupied about 2.2 acres in the Northern Basin and 0.2 acre in the Southern Basin. Phragmites currently occurs along about 75 percent of the Northern Basin shoreline and occupies about 2.6 acres of former open water habitat. Expansion appears to have slowed somewhat in recent years, probably since most suitable shallow water habitat has already been colonized. Phragmites currently occurs along about one-third of the Southern Basin shoreline and occupies about 0.7 acre. A few small stands, totalling less than 0.1 acre, are located elsewhere in the Fens upstream of the Agassiz Bridge. The present location of these stands is shown on Plate F-2 in Appendix F.

Conditions in the Fens are favorable for continued Phragmites expansion. A substantial amount of open water with depth less than 3 feet is present, and vulnerable to Phragmites colonization. Locations that appear most vulnerable include near shore areas downstream of Louis Pasteur Avenue and the remainder of the Southern Basin shoreline. The middle section of the Southern Basin is shallow, but may not be vulnerable to rapid Phragmites expansion because bottom sediments are soft. Wave action may also limit Phragmites expansion in this area. Potential for Phragmites expansion is limited in the Northern Basin, where much of the remaining open water is generally deeper than 3 feet.

Phragmites growth in both the Riverway and Back Bay Fens areas is extremely robust, with the maximum shoot height being 6-7 meters. Phragmites tends to occur in dense, mono-specific stands, which have limited wildlife habitat value. Phragmites preclude growth of other wetland plants such as cattail, bullrush, pickerelweed, and arrowhead which are more beneficial to wildlife and visually less obtrusive. On the positive side, Phragmites does provide some cover for wildlife.

Fisheries Degradation.

Due to poor water quality and habitat, the Muddy River supports a very limited warm water fishery. To obtain data regarding the risks of consuming fish from the river, the Commonwealth of Massachusetts conducted an analysis of Muddy River fish for toxic contaminants. This analysis, conducted in 1990, determined that fish sampled from both the Riverway and Back Bay Fens areas contained high levels of PCBs. Seven of the 14 fish analyzed had PCB levels which met or exceeded the FDA action level of 2 ppm (maximum concentration was 3.4 ppm). Carp with high tissue lipid content had the highest PCB levels. Based on this information, a public health advisory was issued recommending that people not consume carp, brown bullhead, or American eel from the Muddy River, and that consumption of other species be limited to two meals per month. Concentrations of metals in fish were low, and did not exceed FDA action levels.

<u>Recreation.</u>

Recreational usage of the Riverway and Back Bay Fens areas of the Muddy River has been severely impacted by the environmental problems discussed in the previous paragraphs. Specific problems include: odors caused by poor water quality and contaminated sediments during much of the year; high fecal coliform counts that prevent water contact activities; and Phragmites expansion which blocks many views and detracts from the aesthetic value of the park system. These and other less severe problems serve to limit the enjoyment and usefulness of one of the area's most valuable natural resources.

SUMMARY OF PROBLEMS

The primary problems identified in the reconnaissance study are related to flood damages and environmental degradation of the Muddy River. In general these problems are caused by the intense urbanization of the watershed. Flooding is caused by high runoff rates and hydraulic restrictions, and environmental problems are primarily the result of past and present sewage discharges, urban runoff, sedimentation and Phragmites expansion.

EXPECTED FUTURE CONDITIONS

Population in the study area has been relatively constant over the last decade. From 1980 to 1990, Boston's population grew about two percent (from 562,994 to 574,283), while Brookline had a slight population decline (from 55,062 to 54,718). Based on these figures and other projections, the study area is expected to grow relatively slowly in the coming decades. Although intensification of land use, particularly by the numerous medical facilities and others in areas adjacent to the river, is expected to continue, this redevelopment is not occurring within the floodplain. Consequently, it is anticipated that flood damages will remain fairly constant. In addition, since no major development changes are expected to occur in the watershed, the quality and quantity of water and sediment are not expected to change substantially unless corrective measures are implemented to eliminate the sources of pollutants.

FEDERAL OBJECTIVE

The Federal objective of water and related land resource project planning is to contribute to National economic development (NED), consistent with protecting the Nation's environment and applicable statutes and regulations. Accordingly, the benefits of a recommended project (expressed in monetary terms) must exceed its cost.

In addition, for urban areas, minimum flow criteria must be met for Corps of Engineers involvement. This criteria specifies that flood damage problems may only be addressed downstream from the point where the flood discharge is greater than 800 cubic feet per second (cfs) for the 10-percent flood. Exceptions to this criteria may only be granted if the discharge for the one-percent flood exceeds 1800 cfs due to a hydrologic disparity between the 10 and one-percent flood events.

SITE SPECIFIC PLANNING OBJECTIVES AND CONSTRAINTS

Based on an initial evaluation of the existing watershed conditions and discussions with Federal, State, regional and community officials, the following planning objectives were established.

Reduce potential flood losses along the Muddy River.

Identify potential measures to improve the environmental values of the Muddy River and adjacent park lands.

In addition, an overall study objective was that information be sufficiently detailed to determine that at least one potential solution will likely qualify for Federal involvement, and be in accordance with current policies and budgetary priorities.

A constraint related to proposed alternatives is that they not impact the historic integrity and intent of the original park design. Virtually all of the Muddy River and adjacent land areas are within the Emerald Necklace Parks and are listed on the National Register of Historic Places.

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SECTION IV

ALTERNATIVE PLANS

FLOOD DAMAGE REDUCTION

<u>Measures Available to Address the Flood Problem.</u>

To prevent or reduce flooding and associated damage, there are two basic types of protection available; structural and nonstructural. Structural and nonstructural measures differ in that structural measures affect the flood waters while nonstructural measures affect activities in the floodplain. Nonstructural solutions to flood problems are normally applied directly to each floodplain property or activity, in contrast to structural measures which normally affect the floodplain. Both types of flood control measures were considered in this study to address the potential flood problem.

<u>Structural Measures</u> - Structural measures are characterized as those measures that prevent or reduce inundation of the floodplain. The following structural measures, either singularly or in combination with others, represent potential solutions to flooding.

Channel Improvements/Removal of Restrictions

Upstream Reservoirs

Dikes and/or Floodwalls

<u>Nonstructural Measures</u> - Nonstructural flood damage reduction measures are those measures which prevent or mitigate losses experienced by existing flood prone properties and activities, while allowing continued inundation of the floodplain. Typical nonstructural measures are presented below:

Floodproofing of flood prone structures or facilities

Flood forecast, warning and evacuation system

<u>Development, Evaluation and Screening of Flood Damage Reduction Measures</u>

During the initial phase of this reconnaissance study, numerous meetings were held with other Federal, State, regional, community and interested groups and individuals. One purpose of these meetings was to gather information concerning areas susceptible to flooding. In conducting the initial evaluation of flood prone areas, all methods of reducing or eliminating potential flood damages were given consideration. To determine which alternatives warranted further detailed evaluation, an initial screening process was conducted. Factors considered during this process included the potential for flood damage reduction, the possible environmental and social impacts, engineering and economic feasibility, and public acceptability of identified alternatives.

Channel improvements/removal of restrictions - This category of improvement measures was retained for further study because hydrologic and hydraulic analysis of the watershed determined that undersized culverts and sedimentation of the channel are the primary cause of flooding.

Reservoirs - Since the urbanized nature of the watershed makes construction of flood control reservoirs impractical, the possibility of using existing impoundments to store flood water was investigated. The major impoundment in the watershed is Jamaica Pond. However, analysis of the watershed determined that storing flood water at this pond would have very little impact because present outflows do not contribute significantly to flooding. Modifications to the other three ponds is not practical from an engineering or economic standpoint due to the limited amount of available flood storage capacity. In addition, Historic preservation concerns could also preclude structural modifications at these locations. Based on the above, further study of upstream impoundments to store flood flows was not conducted.

Local Protection - During initial evaluation of the feasibility of localized structural plans, two primary factors were considered. First was the presence of the Metropolitan District Commission local protection project along the left bank of the river from Brookline Village to Park Drive. The second was current restrictions placed on modifying riverbank areas due to their historical significance. Due to these two factors and the fact that the primary cause of flooding is restrictive culverts, further analysis of additional dikes or floodwalls was not considered warranted.

Nonstructural - Other than relocation of damageable property, which could be done on a voluntary basis by individual property owners, nonstructural measures are not appropriate solutions to flooding along the Muddy River. The effectiveness of a flood forecasting and warning system would be severely limited because the river's rapid runoff characteristics result in short warning times. These short warning times impact floodproofing alternatives as property owners would, in many cases, have insufficient time to install flood shields or other temporary protective measures. In addition, many structures are of wood frame construction or are nonowner occupied making them inappropriate candidates for floodproofing. Although not considered a flood damage prevention measure, flood insurance is also available to mitigate the effects of flooding.

As a result of this initial screening process, it was determined that alternatives concerning the removal of undersized culverts and increasing channel capacity were the only flood control measures that warranted further study.

Evaluation of Flood Control Alternatives.

To prevent flooding in identified damage zones, two alternative plans were developed. Alternative 1, also referred to as the comprehensive plan, would remove restrictions in all critical areas and provides flood protection to all three damage zones. Alternative 2, or minimum plan, provides for removal of the restrictive culverts upstream of the Brookline Avenue Gate House and only reduces flood damages in Zone 1. A discussion of the details of these alternatives, including their costs, benefits and potential environmental impacts, are presented in the following sections.

Costs for structural plans considered in this report were based on actual costs for similar work which were adjusted to reflect current (November 1992) costs in the Boston, Massachusetts area. The culvert and channel sizes were determined based on hydrologic and hydraulic modeling of the river. To arrive at total first cost, costs for contingencies, engineering and design, and construction management are then added to in-place construction costs. Annual costs were developed using a project economic life of 50 years and the current Federal interest rate of 8 1/2 percent.

Benefits attributable to protective works considered in this study were developed by conducting damage surveys of the study area and correlating these figures with data concerning the frequency and depth of flooding. The annual flood reduction benefits attributable to a plan are then measured by subtracting estimated annual damages remaining after implementation of an alternative plan from total annual damages expected under current conditions. Appendix G details this procedure and provides additional data concerning the economic analysis of alternative plans.

Alternative 1 - Comprehensive Plan - This plan addresses the overall overbank flooding problem which extends from the area upstream of Park Drive to the downstream end of the Back Bay Fens section of the river. The plan consists of two options as follows:

Option A:

Replace the existing twin 6 foot culverts upstream of the Brookline Avenue Gate House with a 10 foot X 20 foot box conduit 535 feet long.

Improve the Muddy River Channel in the Back Bay Fens area from the outlet of the culverts under Brookline Avenue to the Boylston Street bridge. The improved channel would be excavated to -4.0 NGVD, have a bottom width of 30 feet, and side slopes no steeper than 1 vertical on 2 horizontal.

Replace the existing twin 6 foot culverts at Louis Pasteur Avenue with an open channel. This channel would be excavated to -4.0 NGVD, have a bottom width of 30 feet and side slopes no steeper than 1 vertical on 2 horizontal.

This plan has a total estimated first cost of $ 14 million. A breakdown of this cost is shown in Table 3. Plans and sections of Option A are shown on Plates 5, 6 and 8.

Option B:

This option would be the same as option A except that the twin 6 foot culverts upstream of the Brookline Avenue Gate House would be replaced with 200 feet of 10 foot X 20 foot box conduit under the roadway and 335 feet of open channel in the former Sears parking lot. The channel would have a bottom width of 20 feet and side slopes no greater than 1 vertical on 2 horizontal. This open channel provides the opportunity to restore a section of the river that was filled following completion of the park system.

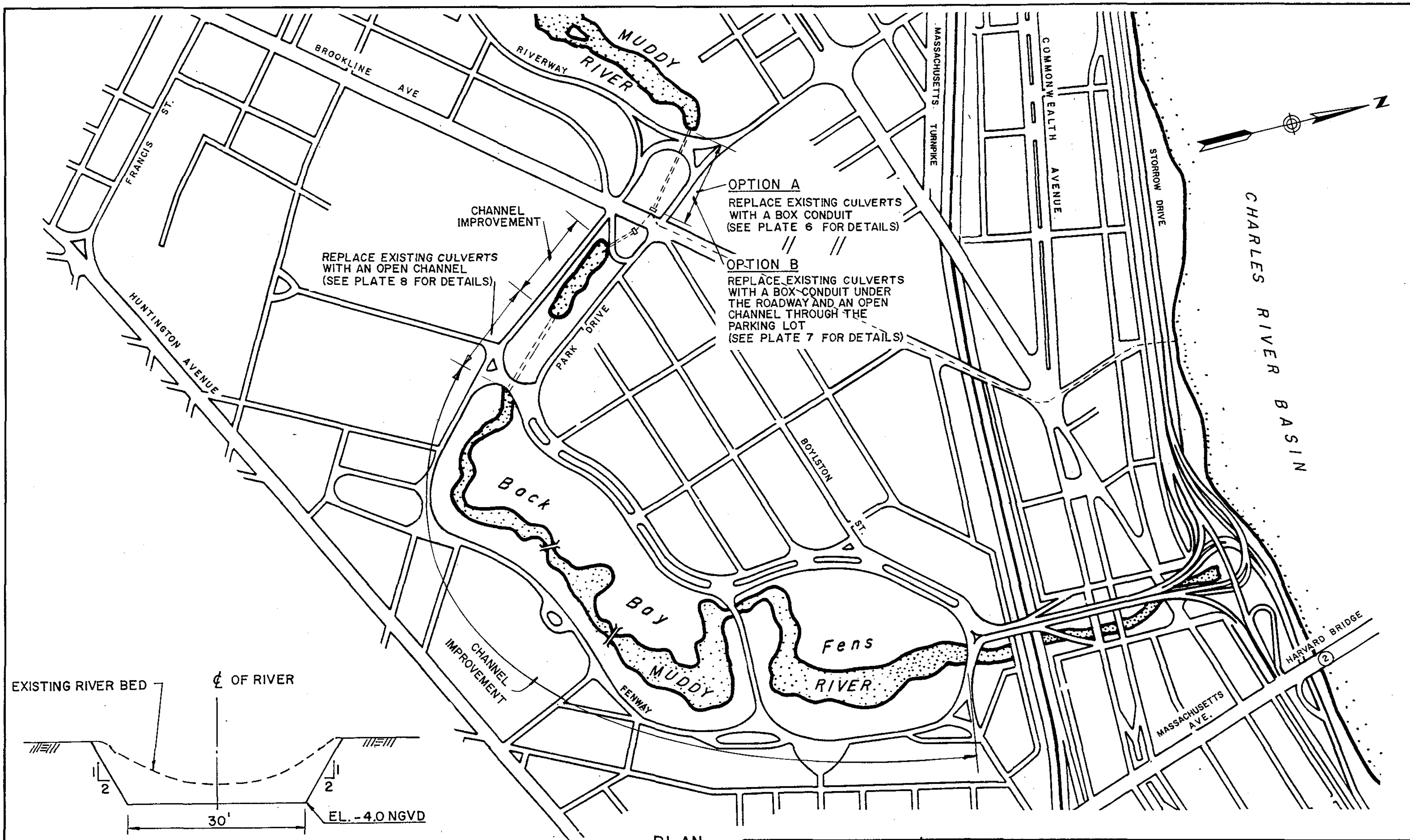
As shown in Table 3, this option has an estimated total first cost of $ 13.5 million. Plans and sections of Option B are shown on Plates 5, 7 and 8.

Environmental Impacts - Replacement of the culverts upstream of Louis Pasteur Avenue with an open channel would restore about 0.4 acres of aquatic habitat. The channel would be situated in approximately the same location as the original Muddy River channel that was filled in the early 1940s. The restored channel would quickly be colonized by aquatic invertebrates, fish, and other aquatic life. Habitat value of the channel would be low, however, without significant improvement in Muddy River water quality. If sediments in the new channel were found to be heavily contaminated, it would be desirable to excavate the channel to below final grade and backfill with clean fill.

Removal of these culverts would probably require diversion of the Muddy River through the Muddy River Diversion Conduit and dewatering of the small upstream pond for several months. Most aquatic life in the pond would be lost, but the area would be quickly recolonized after completion of the project. Water level in the river downstream of the Louis Agassiz Bridge is controlled by the Charles River Dam and would not be affected by the diversion.

Replacement of the culverts upstream from the Brookline Avenue gate house could be done with minimal impacts on aquatic resources. Muddy River flow would be diverted through a temporary culvert while the new box culvert was constructed.

Most of the 5 to 6 acres that would be deepened for the flood control channel is currently open water. Channel improvements would increase the average depth of water in this area from about 2.75 feet to 6.5 feet. To maintain a 30 foot wide channel, several thousand square feet of emergent wetland vegetation would be excavated. Phragmites would be removed near Louis Pasteur Avenue, near the Aggasiz Bridge, and in the Northern Basin. Increased water depth would prevent emergent plants such as Phragmites and Typha from re-colonizing these areas.

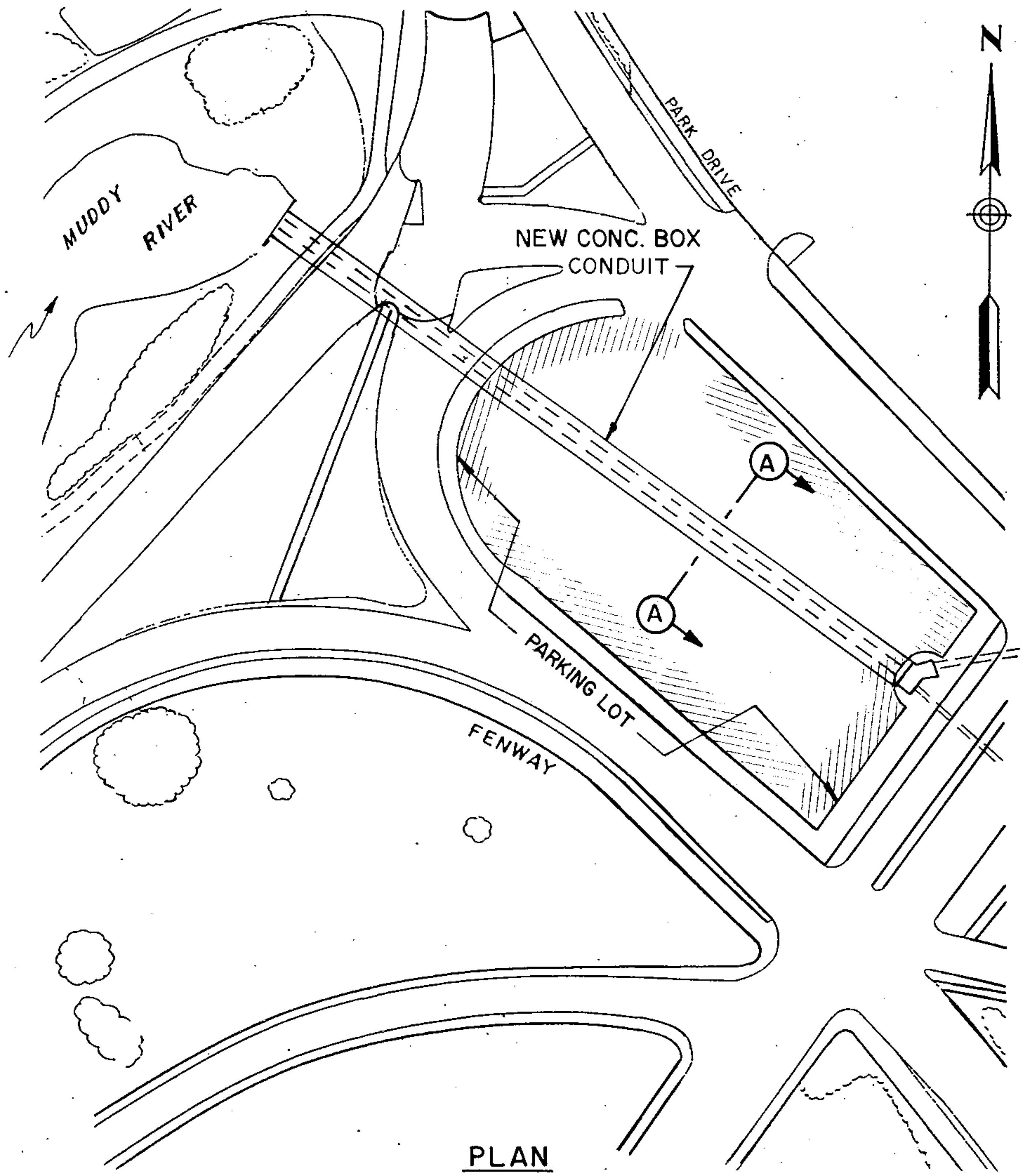


PLAN
SCALE: 1" = 500'

CHANNEL IMPROVEMENT
TYPICAL SECTION
N. T. S.

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	MUDDY RIVER RECONNAISSANCE STUDY FLOOD CONTROL ALTERNATIVE 1 - OPTIONS A&B GENERAL PLAN

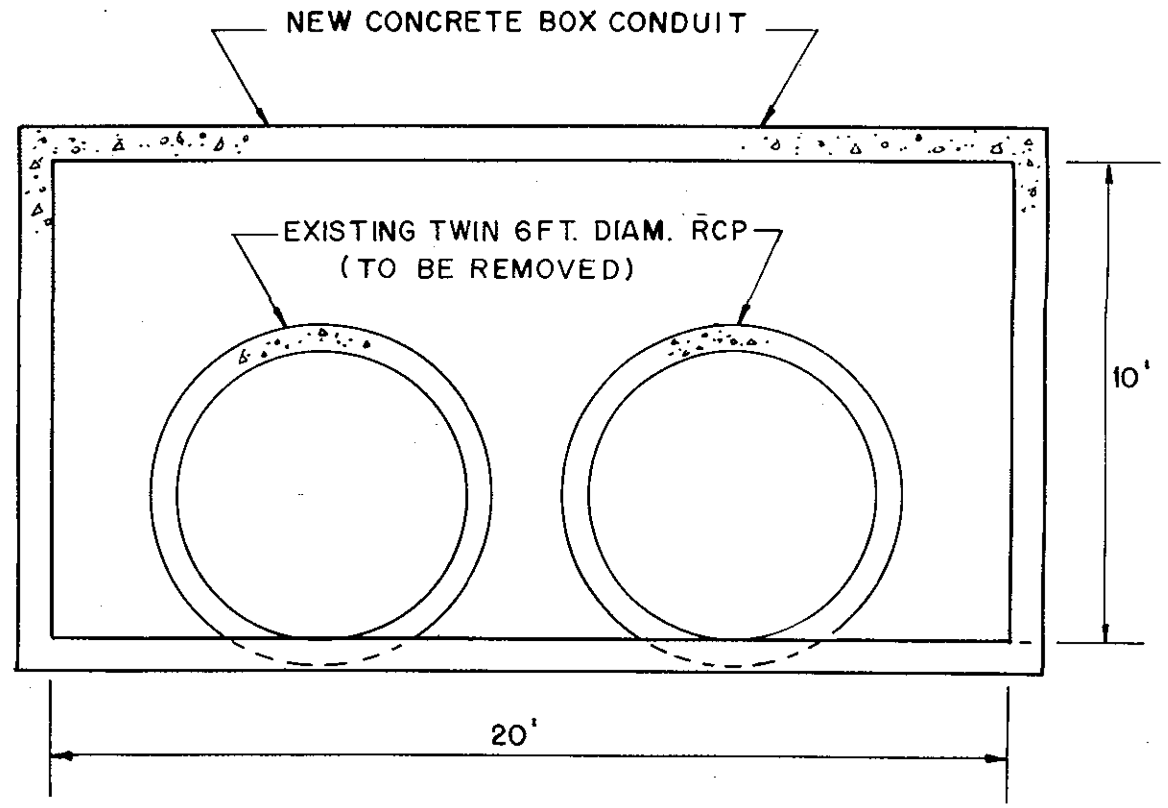
PLATE 5



PLAN
SCALE: 1" = 100'

NOTE:

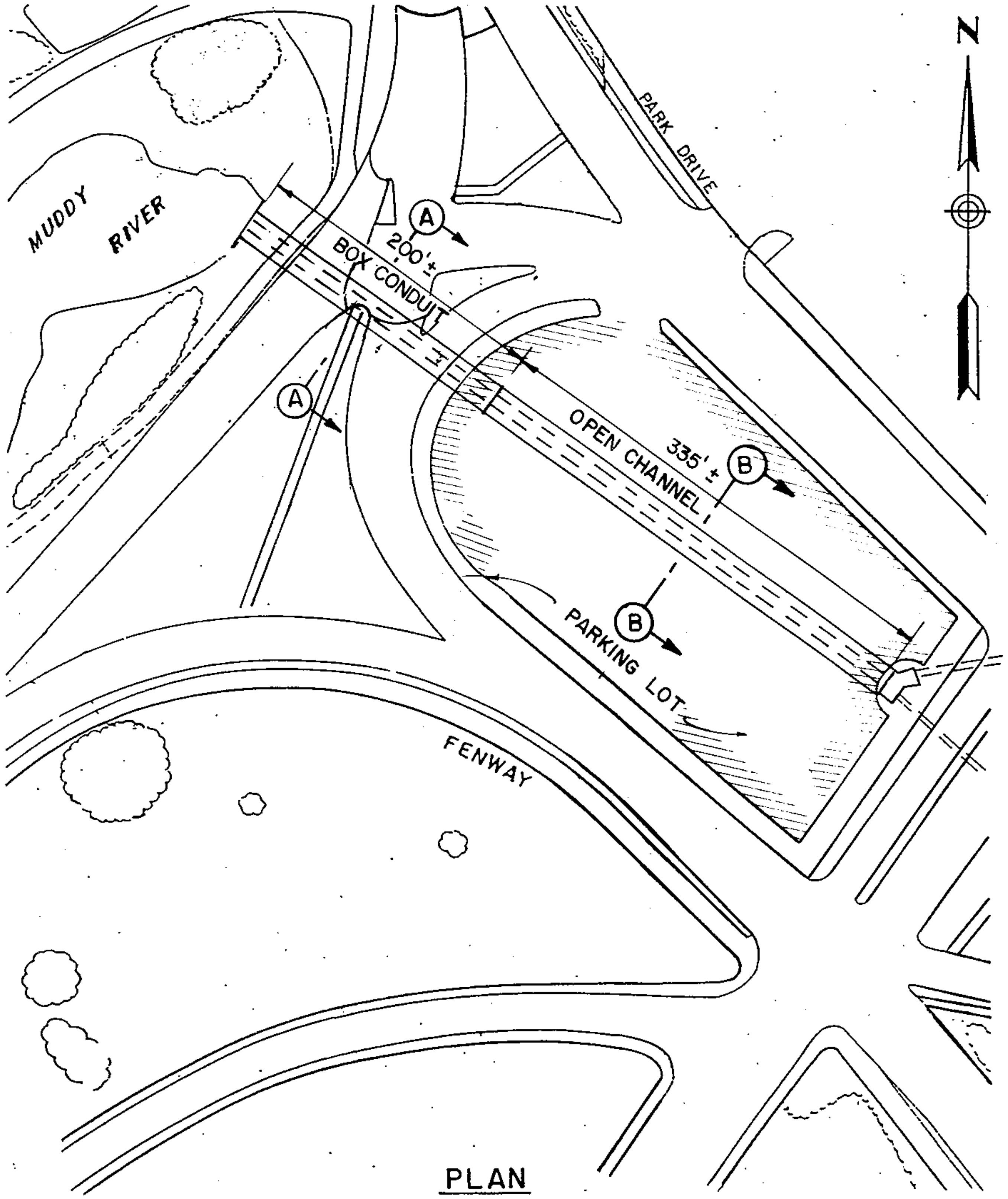
REPLACE 535 L.F. OF TWIN 6FT. DIAM. REINFORCED CONCRETE PIPES (RCP), WITH A 10x20FT. CONCRETE BOX CONDUIT



SECTION A-A
SCALE: 1"= 4'

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	MUDDY RIVER RECONNAISSANCE STUDY FLOOD CONTROL ALTERNATIVE 1-OPTION A CONCRETE BOX CONDUIT PLAN AND SECTION

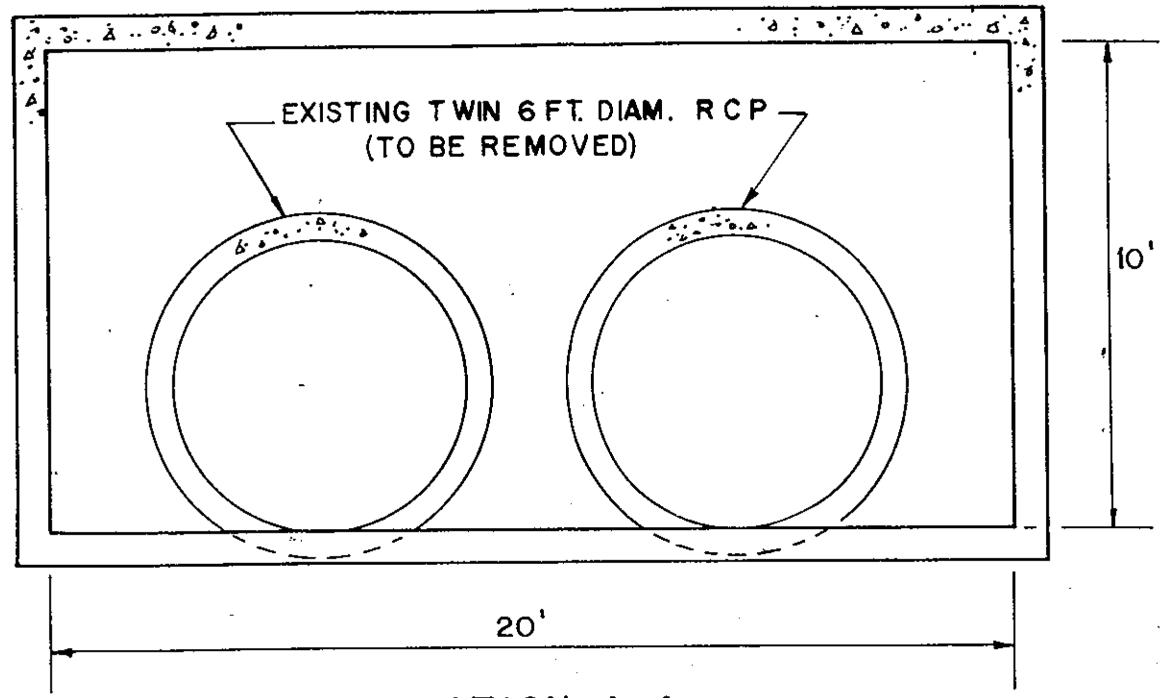
PLATE 6



PLAN

SCALE: 1" = 100'

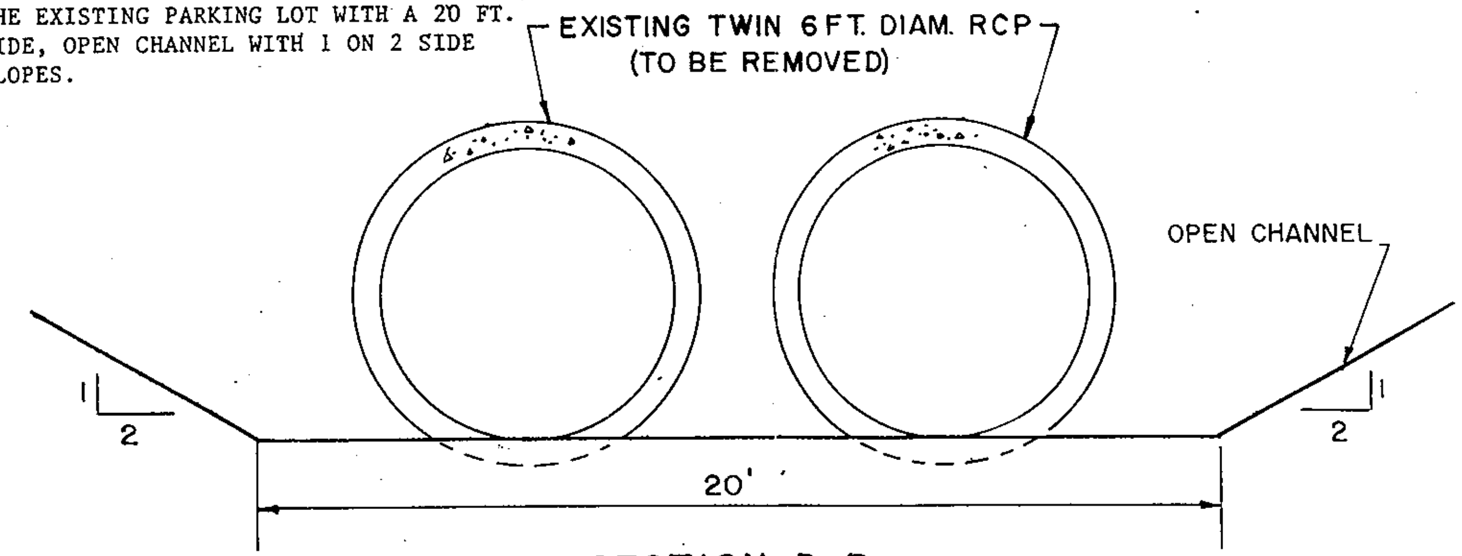
NOTE:
REPLACE 200 LF OF TWIN 6 FT. REINFORCED CONCRETE PIPES (RCP), WITH 10x20 FT. CONCRETE BOX CONDUIT



SECTION A-A

SCALE: 1" = 4'

NOTE:
REPLACE 335 LF OF TWIN 6 FT. DIAM. REINFORCED CONCRETE PIPES (RCP) UNDER THE EXISTING PARKING LOT WITH A 20 FT. WIDE, OPEN CHANNEL WITH 1 ON 2 SIDE SLOPES.

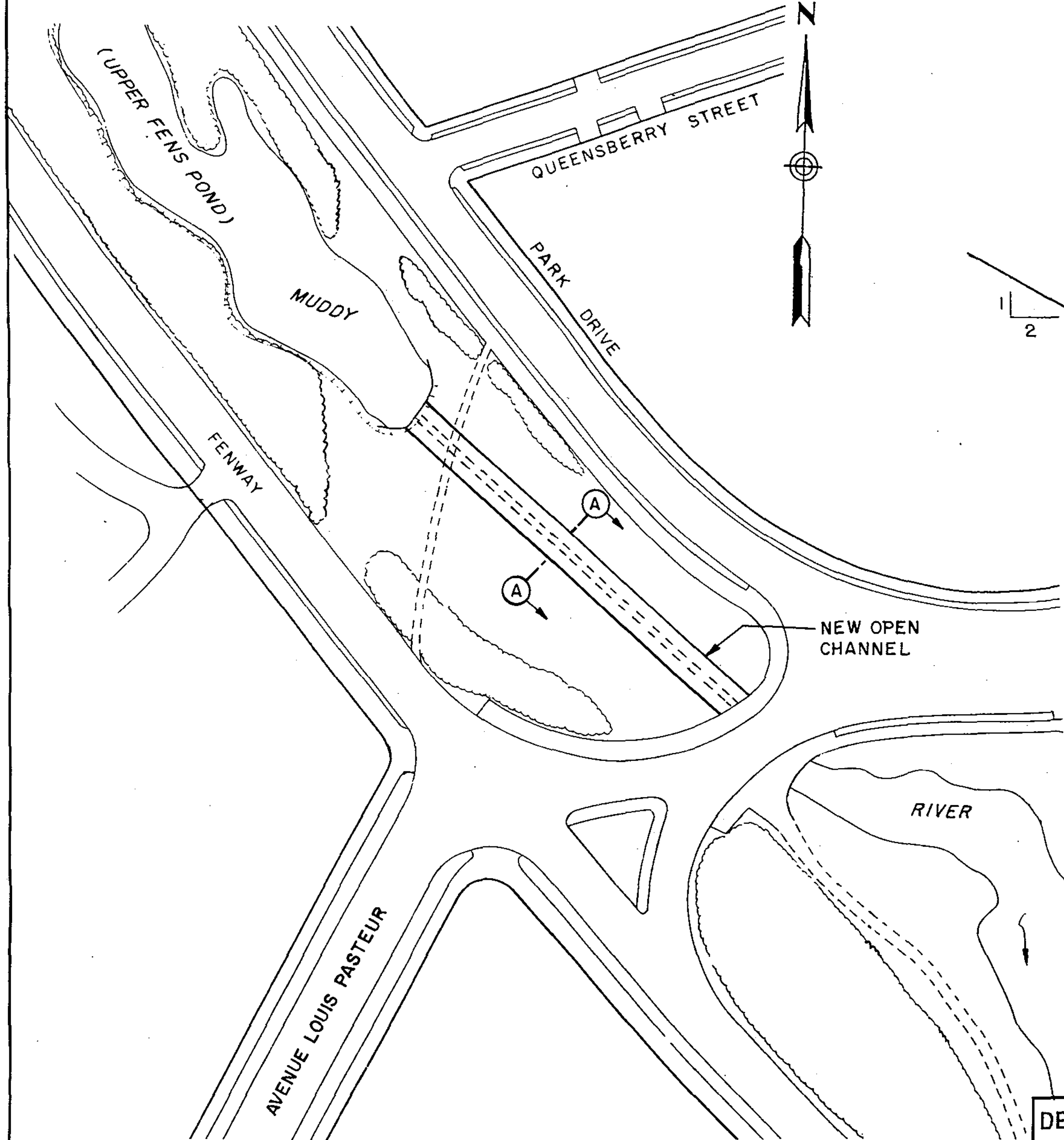


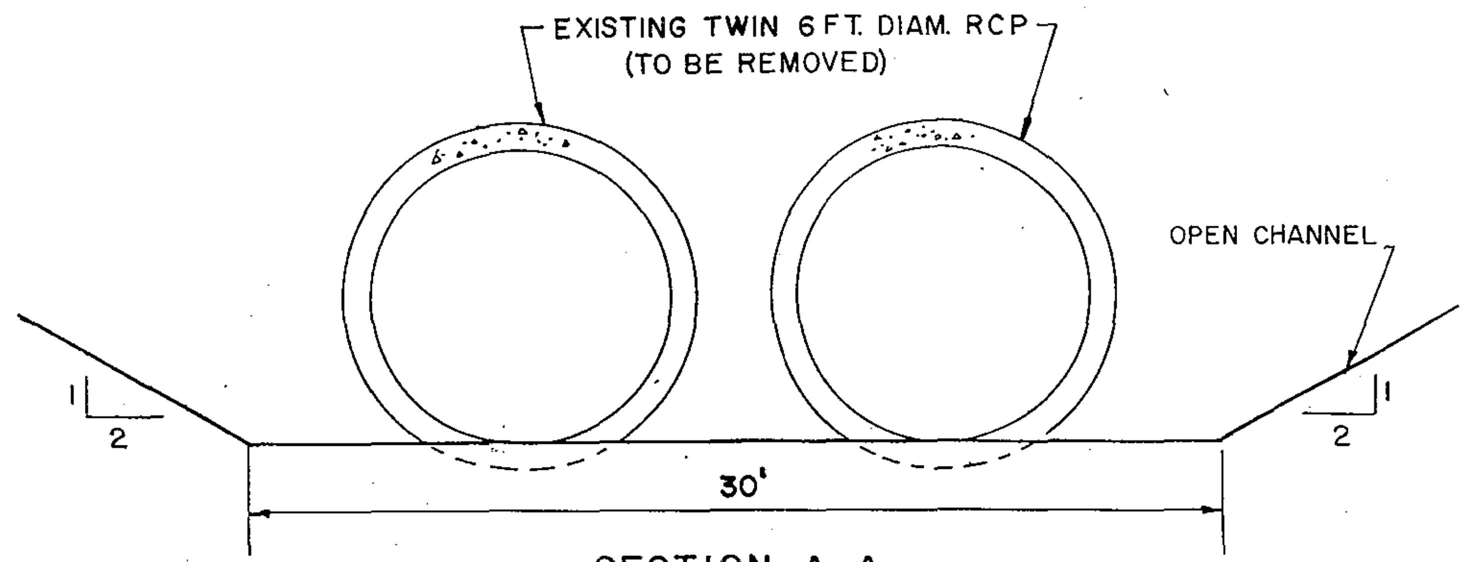
SECTION B-B

SCALE: 1" = 4'

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	MUDDY RIVER RECONNAISSANCE STUDY FLOOD CONTROL ALTERNATIVE 1 - OPTION B OPEN CHANNEL AND CONCRETE BOX CONDUIT PLAN AND SECTIONS

PLATE 7





SECTION A-A
N. T. S.

NOTE:

REPLACE 380'± OF TWIN 6 FT. DIA. REINFORCED CONCRETE PIPES WITH A 30' WIDE OPEN CHANNEL WITH 1 ON 2 SIDE SLOPES

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	MUDDY RIVER RECONNAISSANCE STUDY FLOOD CONTROL ALTERNATIVE 1 - OPTIONS A&B OPEN CHANNEL AT LOUIS PASTEUR AVENUE PLAN AND SECTION

PLATE 8

Channel work would destroy existing invertebrate communities and displace fish occurring in the project area. Mechanical dredging would probably kill some fish through exposure to high suspended sediment levels. Fish eggs and larvae would be especially vulnerable, and it is likely that most individuals of the current year-class would be lost. Hydraulic dredging would greatly reduce fisheries impacts.

Aquatic invertebrates and fish would quickly recolonize excavated areas. Sediments in the new channel would likely be similar to existing sediments and support a similar invertebrate community. Fish community composition would not appreciably change unless much more extensive channel work was conducted. Channel excavation or other modifications would have no impact on the threespine stickleback population, which occurs in the Muddy River well upstream of the work area.

Replacement of the culvert upstream of the Brookline Avenue Gate House would require clearing a few large trees from the former Sears parking lot. Additional vegetation would be cleared from the riverbank near the existing outlet. Disturbed areas would be replanted with trees and shrubs. Several thousand square feet of turf would be disturbed, but would be restored after completion of the project.

Restoring the Muddy River channel upstream of the Louis Pasteur Avenue Bridge would eliminate about 0.5 acre of existing turf. About 20 large trees growing near the existing culvert inlet would be lost. Turf would be replaced with about 0.4 acre of riparian habitat along side slopes. Side slopes would be landscaped with trees and shrubs, possibly similar to those specified by Olmstead in the original Muddy River planting plans.

A staging area would be required near the river for equipment storage and dewatering excavated material. The location of this area was not specifically determined, but the area would require restoration following completion of the work.

Channel excavation would likely destroy some shallow water or mudflat habitat used by wading birds and turtles.

Work on the culverts upstream from the gate house would disrupt traffic and reduce available parking in the area for several months. Parking is already limited in the area, and this could impose a hardship on local businesses and the public. Recreational use and enjoyment of the area would be disrupted by construction equipment and noise.

Connecting the Upper Fens Pond with rest of Muddy River below the Louis Pasteur Avenue Bridge would improve aesthetics in the area and help restore Olmsted's vision of the park. Loss of lawn situated upstream of the bridge would not significantly impact on recreation since it appears to be little used, and substantial other open-space is present in the area.

Construction activities, particularly channel work, would distract from recreational use of the area for several months. The necessary hydraulic lines and dewatering facilities would

TABLE 3
COST ESTIMATES - ALTERNATIVE 1

OPTION A:

Item	Cost
New Concrete Box Culvert Upstream of the Brookline Avenue Gate House	$1,260,000
Channel Improvements	9,070,000
Replace the Conduits at Louis Pasteur Avenue with an Open Channel	170,000
Subtotal	$10,500,000
Contingencies (20 %)	2,100,000
Total Construction Cost	$12,600,000
Planning, Engineering and Design	800,000
Construction Management	600,000
TOTAL FIRST COST	$14,000,000

OPTION B:

Item	Cost
New Box Culvert and Open Channel Upstream of the Brookline Avenue Gate House	$840,000
Channel Improvements	9,070,000
Replace the Conduits at Louis Pasteur Avenue with an Open Channel	170,000
Subtotal	$10,080,000
Contingencies (20 %)	2,020,000
Total Construction Costs	$12,100,000
Planning, Engineering and Design	800,000
Construction Management	600,000
TOTAL FIRST COST	$13,500,000

be unsightly. Truck traffic to dispose of dewatered material would also exacerbate traffic problems in the area.

The impacts for option B are similar to those of Option A (presented above) except that it would create an additional 0.4 acre of riverine and riparian habitat. This would provide a partial link between the Riverway and Back Bay Fens. Perhaps the greatest benefit would be improved aesthetics and reestablishment of a nearly unbroken pedestrian walkway along the river. The channel would also enhance wildlife movement between the Riverway and Fens to some extent, although wildlife transiting the area would still need to negotiate two busy roadways. These benefits would be at the expense of about 175 parking spaces currently available at the Sears parking lot.

<u>Water Quality Impacts</u> - Due to the improved channel capacity in the Fens, this plan would result in additional flow entering the Fens during storm events. This would improve the flushing characteristics in the Fens during these events. However, additional organic sediments may be transported to the Fens. During nonstorm periods, stagnant conditions with little flushing capability would continue to be a problem.

Less sedimentation and greater scouring of fine organic materials would take place upstream in the Muddy River where there would be a slight increase in hydraulic gradient. Increased flushing of upstream sediments during storms may result in increased sedimentation within the Fens area. Even though some added sediment may be transported into the Charles River Basin from the Fens, it is likely that net sediment deposition in the Fens will increase due to its large channel area, sluggish velocity and low hydraulic gradient. This plan would help in decreasing benthic demand of organic sediments in the upstream Muddy River, but the Back Bay Fens area may suffer. Making a portion of the culvert an open channel (near Louis Pasteur Avenue) would provide more surface area for re-introduction of dissolved oxygen. It would be extremely hard to measure minor water quality improvements associated with these culvert changes.

Channel excavation would temporarily increase levels of suspended sediments, nutrients, and metals in the water column, and decrease dissolved oxygen concentration. The extent of water quality impacts would depend largely on the equipment used. Hydraulic dredging would likely have minor, localized water quality impacts. Mechanical dredging, however, would probably have severe short-term water quality impacts. Dissolved oxygen and contaminant levels would likely violate criteria established to protect aquatic life.

Dredging for flood control would probably result in a slight improvement in water quality since filamentous algal blooms would not occur in the dredged channel due to low light availability. Extensive shallow, nutrient rich, sediments would remain, however, and blooms would continue in these areas unless much more extensive dredging was conducted.

Excavation and proper disposal of these highly contaminated sediments will be beneficial to water quality, since the Muddy River and Back Bay Fens are currently acting as a settling area for sewage sludge and organic and inorganic storm drainage pollutants. Anaerobic biodegradation in thesesettled sludge areas of the Muddy River and Fens, although being one of nature's organic cleaning processes, is extremely slow in comparison to what would occur in an aerobic condition. As a result, harmful metal releases and low dissolved oxygen levels linger, making the water column unhealthy for a longer period of time. There would be a short term beneficial impact to water quality after dredging is completed, due to reduced benthic demand. However, with time and no source control, dry weather sewage flows, wet weather combined sewer overflows, and wet weather storm drainage flows would all settle out once again in the same dredged areas. High organic and metal sludges from these pollutant sources will again result in a high benthic demand throughout the area.

The water quality effects of Option B would be similar to those described above, except that a change to open channel conditions for a portion of this reach upstream from the Brookline Avenue Gate House would provide more surface area for reintroduction of dissolved oxygen during various flow conditions. However, this minor water quality improvement would be hard to measure.

<u>Economic Analysis</u> - The costs of Alternative 1 - Options A and B, and their associated annual costs and benefits are presented below:

	Option A	Option B
Total First Cost	$14,000,000	$13,500,000
Annual Cost	$1,210,000	$1,170,000
Annual Benefit	$40,000	$40,000
Benefit-Cost Ratio	0.03	0.03

As shown above, the annual cost of these flood control improvements far exceeds annual flood damage reduction benefits and further study of these alternatives is not economically justified.

In addition to this lack of economic justification, the 10 and 100-year floods fail to meet minimum criteria established for Corps involvement in most locations. This criteria requires that the flow for a 10-year flood event exceed 800 cfs and/or the 100-year flow exceed 1,800 cfs. With improved conditions, the flow upstream of Park Drive for the 10 and 100-year events would be 750 cfs and 1,100 cfs respectively. The minimum flow criteria is only met downstream of the Stony Brook Overflow where improved condition flows would be 890 cfs (10-year event) and 1,870 cfs (100-year event).

<u>Alternative 2 - Minimum Plan</u> - This plan addresses the primary hydraulic restriction posed by the twin 6 foot culverts upstream of the Brookline Avenue Gate House. The design of improvements in this area was predicated on the capacity of the culverts exiting the gate house so that these improvements would not worsen downstream flood conditions. As in

Alternative 1, two options of this plan were developed. These options consist of the following:

Option A:

This option consists of replacing the existing twin 6 foot culverts upstream of the gate house with a 10 foot X 15 foot box conduit, 535 feet long. This option has an estimated cost of $ 1,720,000 (see Table 4). Plans and sections are shown on Plates 9 and 10.

Option B:

This option consists of replacing 200 feet of existing twin 6 foot culverts under the roadway with a 10 foot X 15 foot box conduit and replacing the remaining 335 feet of culverts (the portion under the former Sears parking lot) with an open channel. This channel would have a bottom width of 20 feet and side slopes no steeper than 1 vertical on 2 horizontal. As shown on Table 4, this option has an estimated first cost of $ 1,225,000. See Plates 9 and 11 for plans and sections of this option.

Environmental Impacts - The impacts of this alternative are identical to those presented for Alternative 1 concerning work on the culvert upstream of the Brookline Avenue Gate House. Major adverse impacts include traffic problems, lost parking, and disruption of recreational activities. Impacts to aquatic life would be minimal. As stated for Alternative 1, an open channel (Option B) has advantages over a box conduit since it would restore some riparian/aquatic habitat and improve recreational access between the Riverway and Back Bay Fens.

Water Quality Impacts - Aternative 2 would produce a flatter hydraulic gradient than Alternative 1 since there would still be a constriction upstream of Avenue Louis Pasteur. The result will be less scouring of organic sediment in the upstream Muddy River, and lesser movement of sediments into the Back Bay Fens area than Alternative 1. Again, water quality changes relative to culvert modifications and/or restoration of a section of open channel, would be hard to measure.

Economic Analysis - The following tabulation presents the costs, benefits and resultant benefit cost ratios of Alternative 2 - Options A and B.

	Option A	Option B
Total First Cost	$1,720,000	$1,225,000
Annual Cost	$148,700	$105,900
Annual Benefit	$29,000	$29,000
Benefit-Cost Ratio	0.20	0.27

The above analysis determined that the costs of replacing the culverts upstream of the Brookline Avenue Gate House exceed flood control benefits and further study of these alternatives is not warranted. In addition, as in Alternative 1, improved condition flows in this area would fail to meet the minimum flow criteria required for Corps involvement.

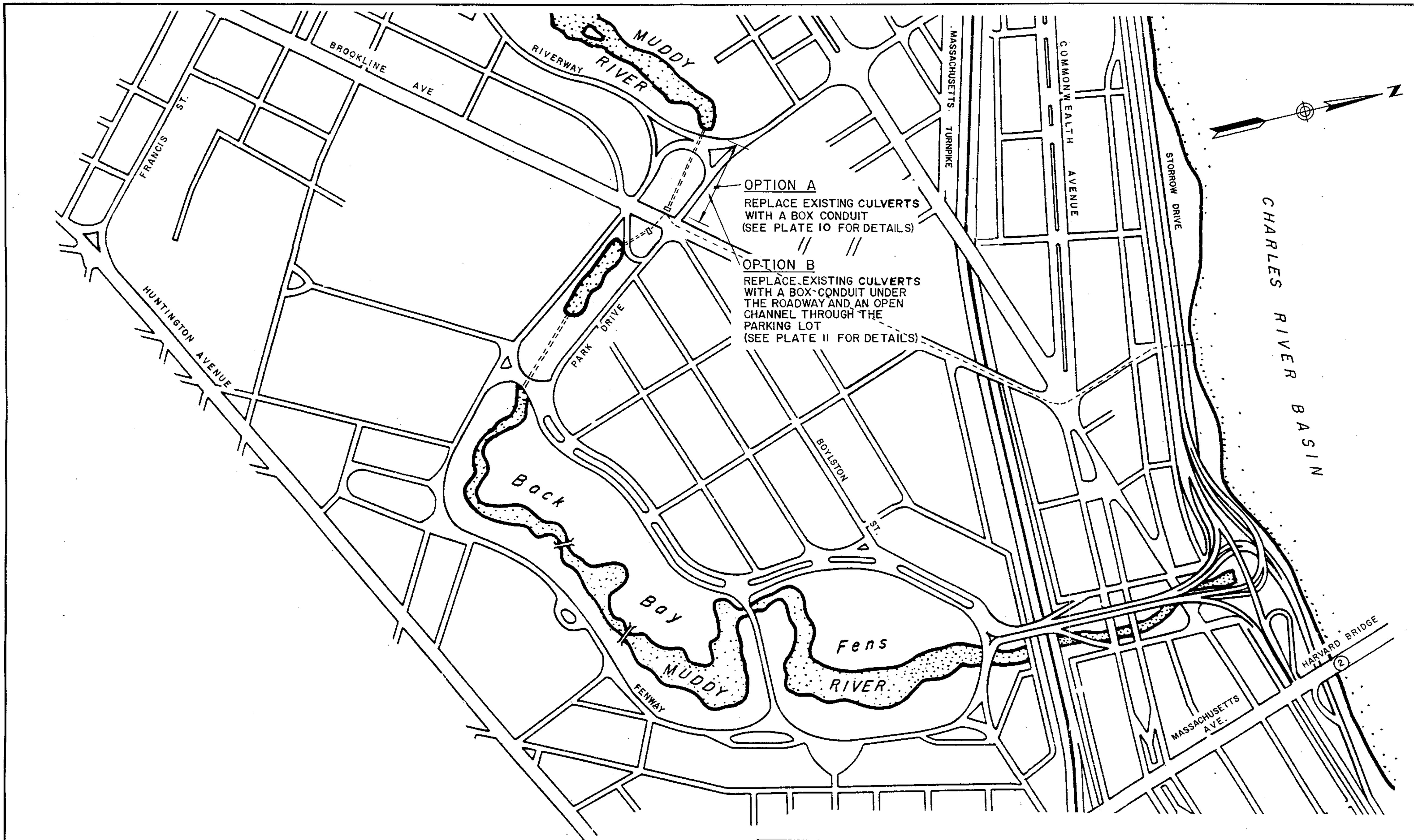
TABLE 4
COST ESTIMATES - ALTERNATIVE 2

OPTION A:

Item	Cost
New Concrete Box Culvert Upstream of the Brookline Avenue Gate House	$1,165,000
Contingencies (20 %)	235,000
Total Construction Cost	$1,400,000
Planning, Engineering and Design	240,000
Construction Management	80,000
TOTAL FIRST COST	$1,720,000

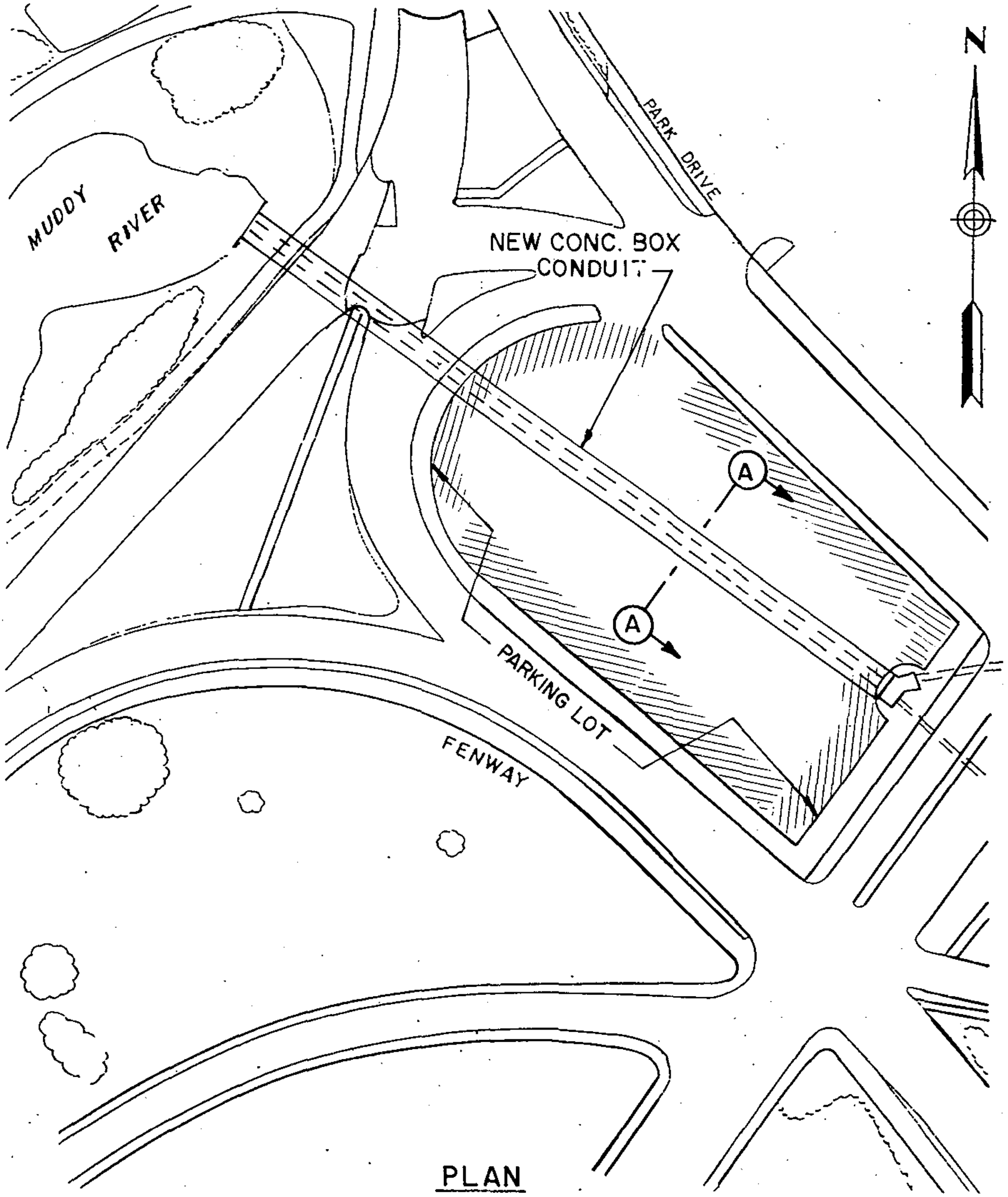
OPTION B:

Item	Cost
New Box Culvert and Open Channel Upstream of the Brookline Avenue Gate House	$755,000
Contingencies (20 %)	150,000
Total Construction Costs	$905,000
Planning, Engineering and Design	240,000
Construction Management	$80,000
TOTAL FIRST COST	$1,225,000



DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	MUDDY RIVER RECONNAISSANCE STUDY FLOOD CONTROL ALTERNATIVE 2-OPTIONS A&B **GENERAL PLAN**

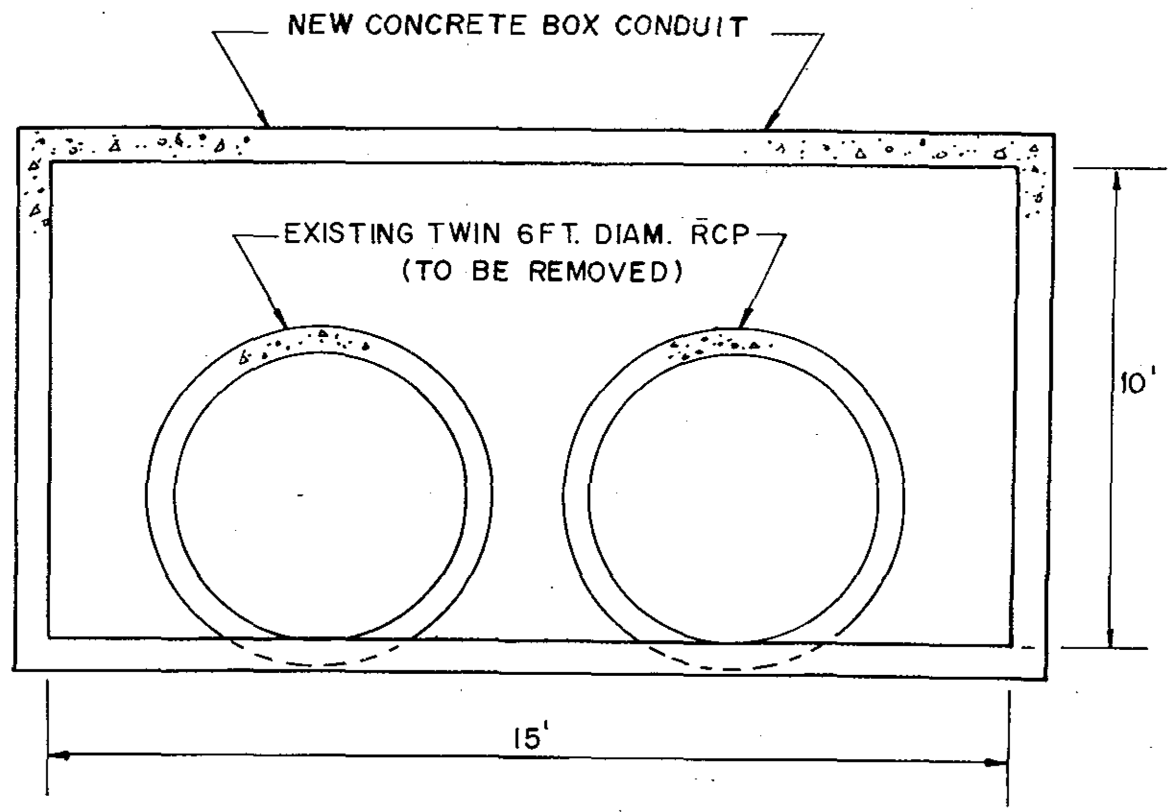
PLATE 9



PLAN
SCALE: 1" = 100'

NOTE:

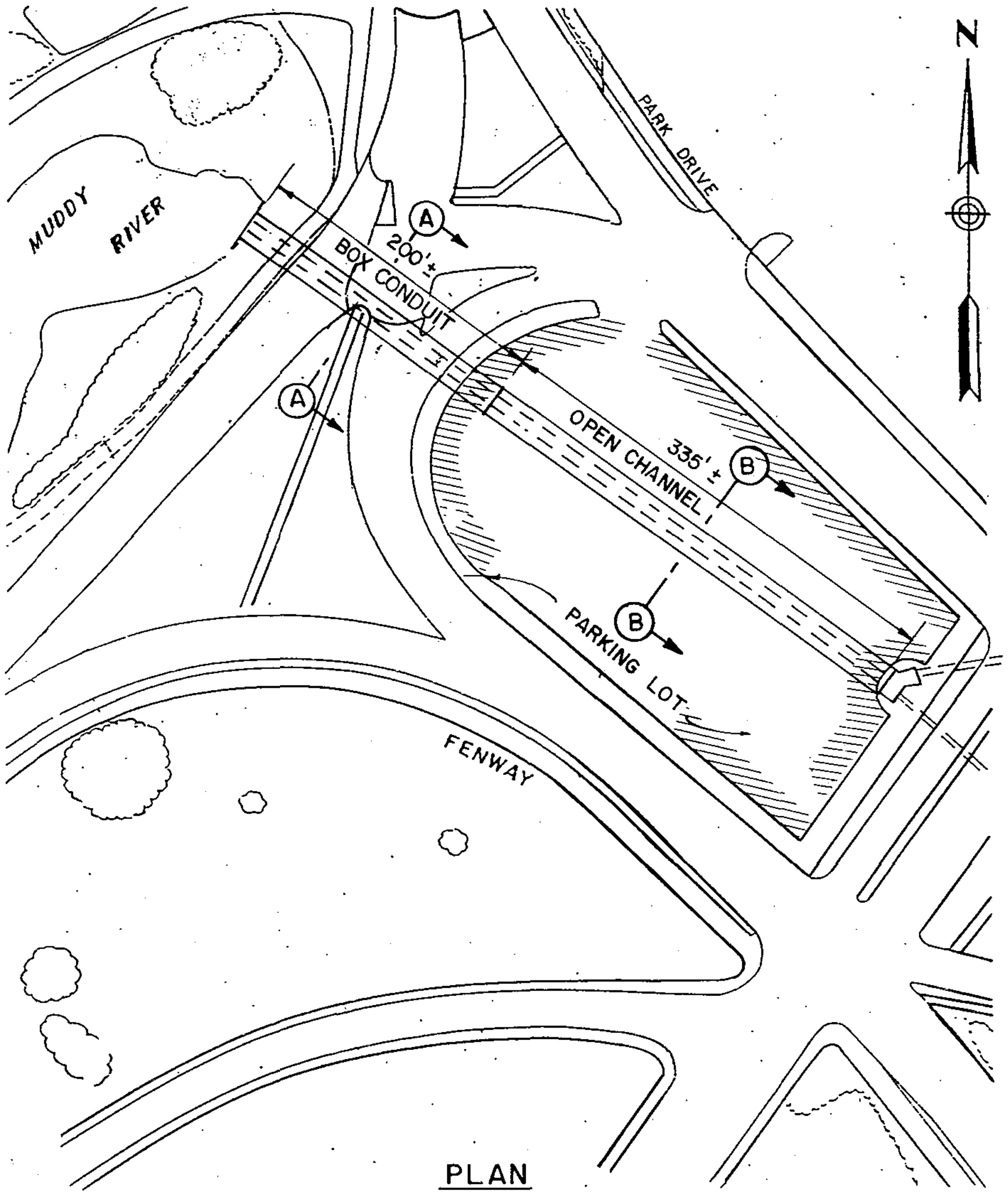
REPLACE 535 L.F. OF TWIN 6 FT. DIAM. REINFORCED CONCRETE PIPES(RCP), WITH A 10 x 15 FT. CONCRETE BOX CONDUIT



SECTION A-A
N. T. S.

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	MUDDY RIVER RECONNAISSANCE STUDY FLOOD CONTROL ALTERNATIVE 2-OPTION A CONCRETE BOX CONDUIT PLAN AND SECTION

PLATE 10

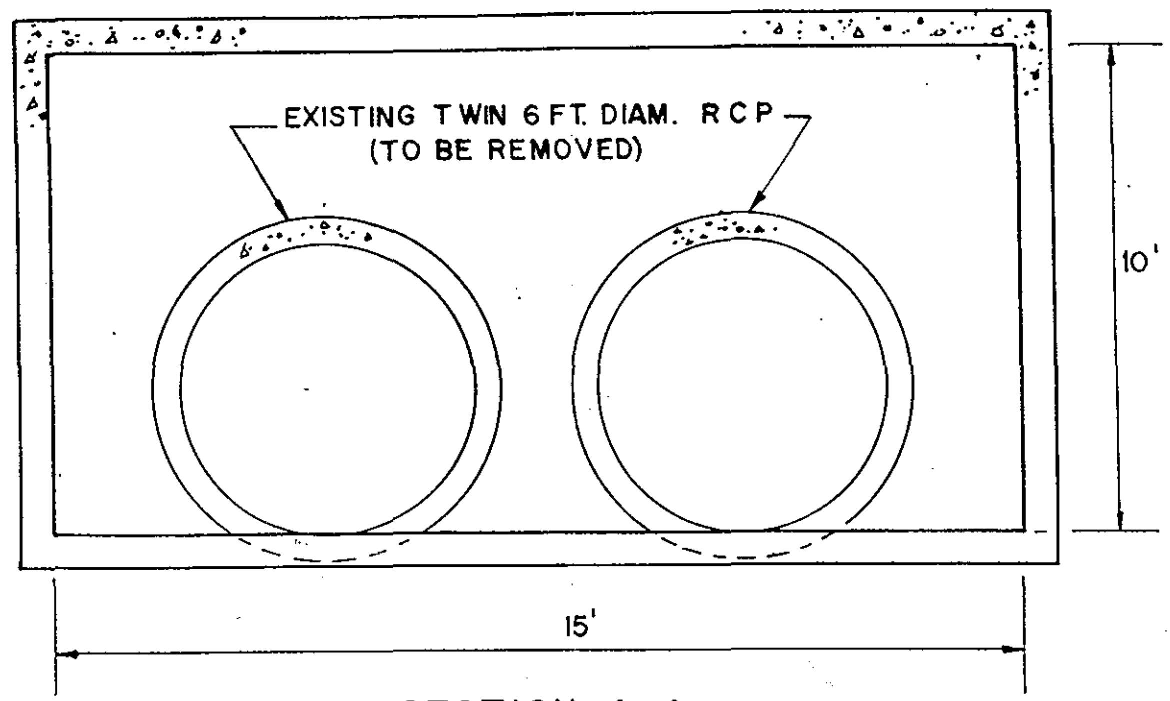


PLAN

SCALE: 1" = 100'

NOTE:

REPLACE 200 LF OF TWIN 6 FT. REINFORCE CONCRETED CONCRETE PIPES (RCP), WITH 10x15 FT. CONCRETE BOX CONDUIT

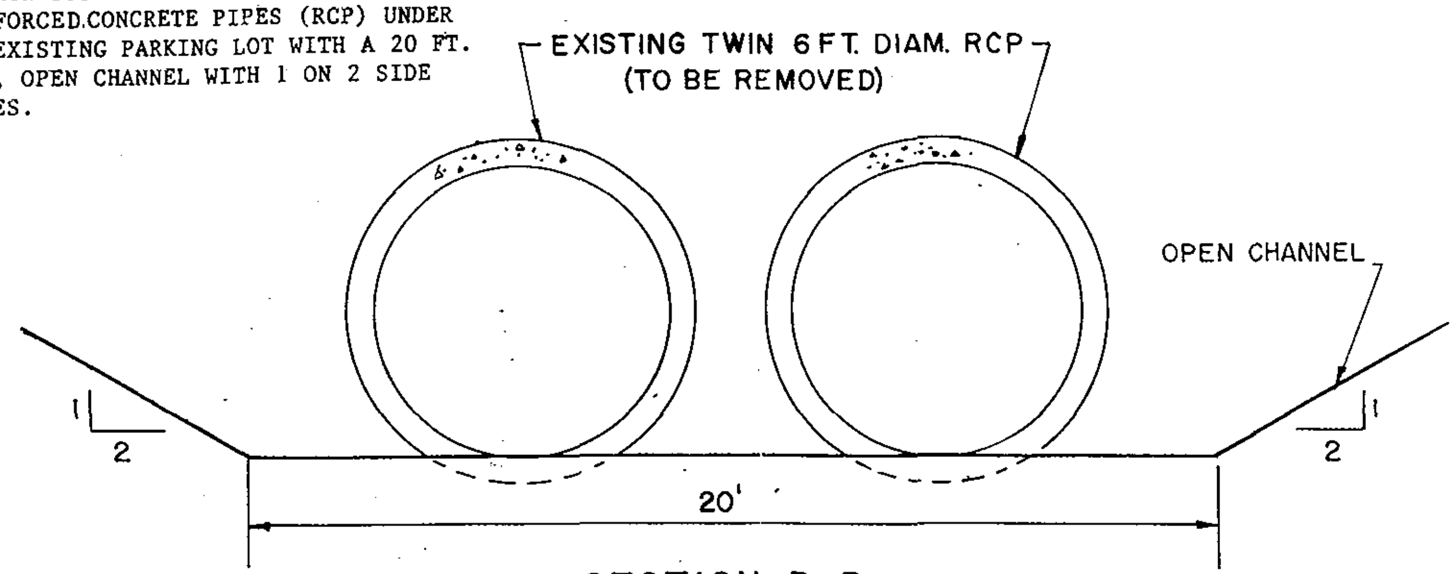


SECTION A-A

N. T. S.

NOTE:

REPLACE 335 LF OF TWIN 6 FT. DIAM. REINFORCED.CONCRETE PIPES (RCP) UNDER THE EXISTING PARKING LOT WITH A 20 FT. WIDE, OPEN CHANNEL WITH 1 ON 2 SIDE SLOPES.



SECTION B-B

SCALE: 1" = 4'

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	MUDDY RIVER RECONNAISSANCE STUDY FLOOD CONTROL ALTERNATIVE 2 - OPTION B OPEN CHANNEL AND CONCRETE BOX CONDUIT **PLAN AND SECTIONS**

PLATE II

ENVIRONMENTAL CONSIDERATIONS

As a result of major environmental problems identified in the watershed, the following measures to improve water quality, dispose of contaminated sediments and control Phragmites expansion were developed. Inasmuch as the Corps of Engineers has no authority in the Muddy River to implement projects solely for environmental enhancement, these alternatives are presented to assist State and local agencies in their efforts to improve the environment of the Muddy River.

Water Quality Improvement Measures.

Although no one procedure will solve all water quality problems in the Muddy River, the following major categories of measures in various combinations can be expected to significantly improve the river's water quality and riverine habitat: source control, instream treatment/dissolved oxygen addition and flow augmentation.

Source Control - The highest priority source control projects that would provide the best opportunity for Muddy River water quality improvement are the elimination of sewer cross connections from the Daisy Field, Tannery Brook, Village Brook, and Longwood Avenue drainage systems so that there are no dry weather sewage discharges to the river. In addition, Brookline and Boston should implement or maintain best management practices to reduce storm drain pollutants. Other possible alternatives, not recommended at the present time due to the difficulty in implementation or need for more information and study, include: elimination of combined sewer overflows (CSOs), sewer siphon improvement, and a system of gross particle collectors. Further investigation and significant financial commitment may make these latter options viable in the future.

Implementation of source control measures are essential to reduce further nutrient and contaminant loading into the river. Although the above methods would improve water quality, existing organic and nutrient rich sediments would continue to exert a high oxygen demand and release nutrients, particularly phosphorus, into surface waters and summer algae blooms would likely continue. High levels of metals would remain in sediments and continue to be released, exceeding levels likely to adversely affect aquatic life. Petroleum hydrocarbon and PCB levels would decline at very slow rates due to natural bacterial degradation and resuspension of these contaminants may occur during storm discharges.

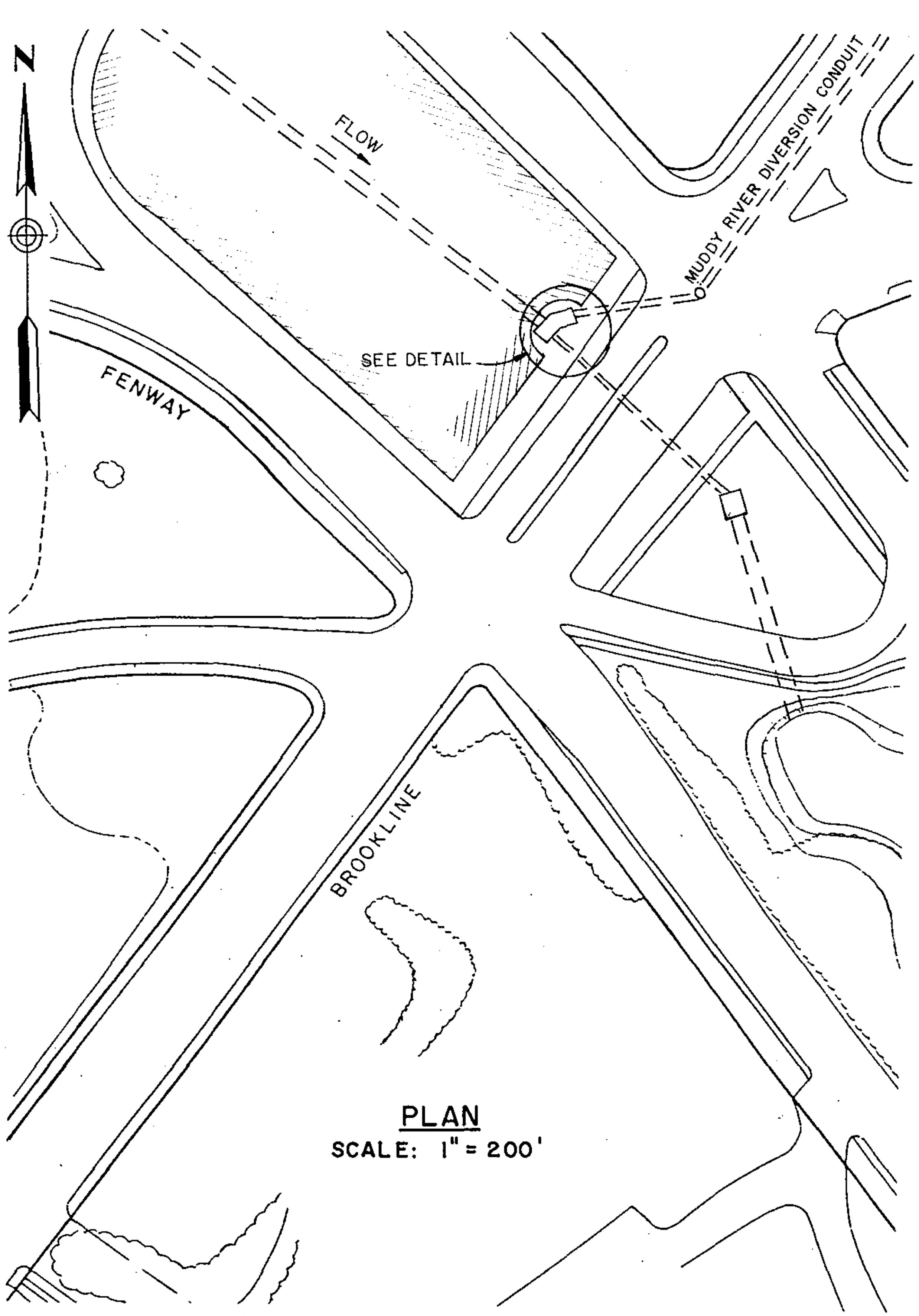
In-Stream Treatment/Dissolved Oxygen Addition - Depending on how elaborate the treatment and/or aeration scheme, this program may be the least costly and one of the easiest to implement. Water quality impacts will be immediate since the system will treat the symptoms of a highly polluted stream by accelerating nature's self-cleansing properties. Ideally a system would be designed to maintain acceptable DO levels in the Riverway and Back Bay Fens throughout the critical summer low flow period. A demonstration project, which includes the installation of both rock trickling filter and rotating biological contactor

units to demonstrate the effectiveness of stream side treatment, has been proposed by Northeastern University. This proposal is currently under consideration by the EPA for possible funding under the Section 104 (b) grant program.
Maintaining high DO levels would reduce release of phosphorus, metals, and hydrogen sulfide from sediments. If source controls were also in place to control nutrient loading, the severity of algal blooms could probably be reduced and conditions for aquatic life generally improved. Complete elimination of blooms in the Back Bay Fens seems unlikely, however, given the existing shallow water conditions and nutrient rich sediments. Further water quality study of the Riverway and Fens would be needed to further evaluate this alternative and develop design parameters. As discussed in the "Source Control" section, the high levels of contaminants remaining in river sediments would continue to pose a threat to aquatic life.

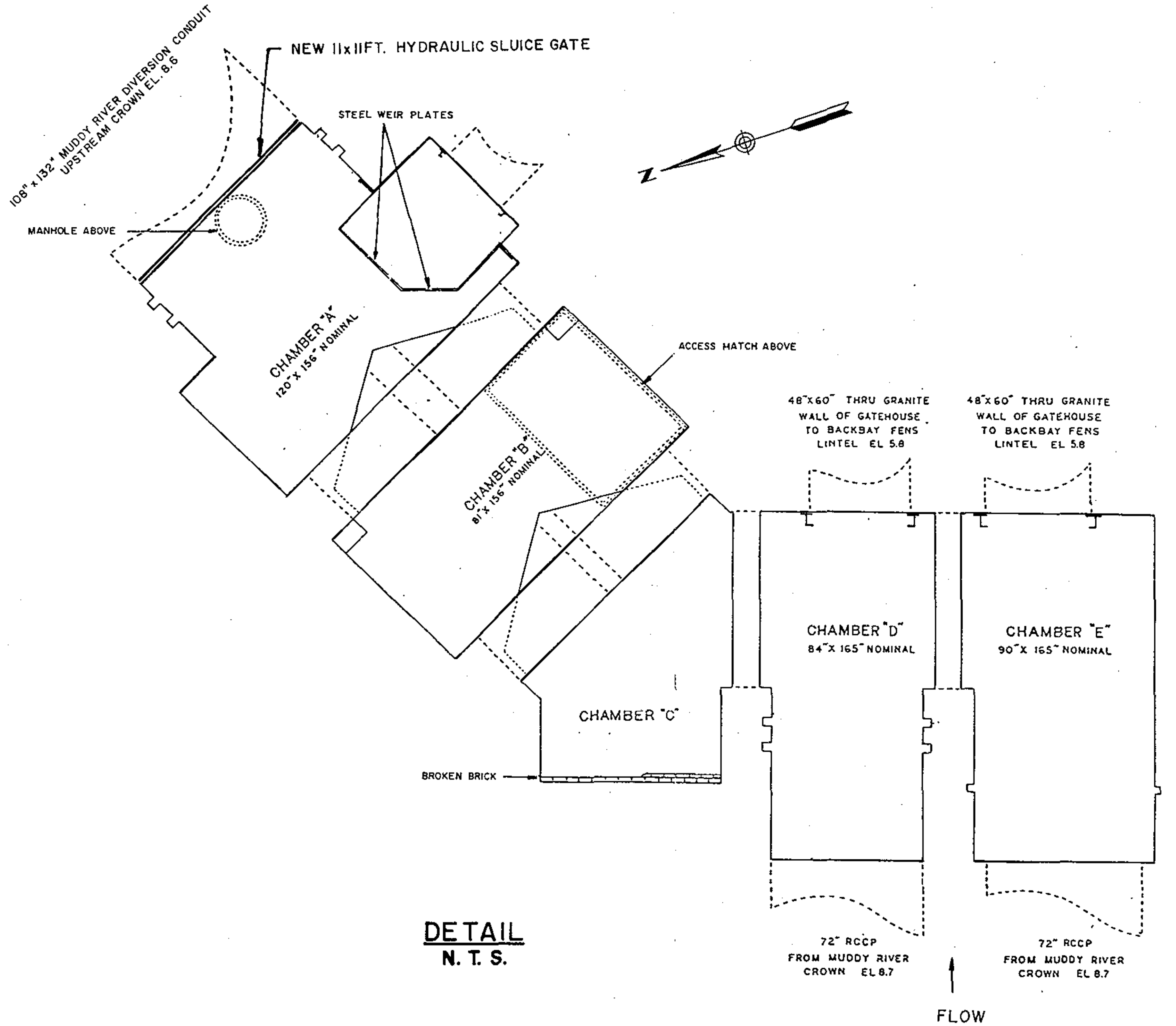
Operation of filtration or aeration systems would have minimal environmental impacts. Since space near the river would be required to site the required facilities, care would be needed to avoid adverse impacts on historic resources and aesthetics. As in source control, no estimates of the cost of these systems were made as development of the required data was beyond the scope of the study.

Flow Augmentation - Flow augmentation appears to be a long term requirement for maintaining a healthy riverine environment within the Muddy River since it will deter sedimentation, increase DO levels and help maintain the river's assimilation capacity. Although flow augmentation can be accomplished in many ways, the ones recommended for consideration at the present time, due to their ease of implementation are: modification of the Brookline Avenue Gate House by installing a gate to divert more flow to the Back Bay Fens area, and release of municipal or well water to the upper Muddy River. Certainly, source control improvements must accompany these measures.

A plan showing the possible location of a diversion gate within the Brookline Avenue Gate House is included as Plate 12. The cost of this plan, estimated at $ 200,000, is shown in Table 5.



PLAN
SCALE: 1" = 200'



DETAIL
N. T. S.

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.	MUDDY RIVER RECONNAISSANCE STUDY DIVERSION GATE PLAN AND DETAIL

PLATE 12

TABLE 5
COST ESTIMATE - INSTALL DIVERSION GATE

Item	Cost
Hydraulic Sluice Gate (including installation)	$70,000
Sediment Removal	35,000
Subtotal	$105,000
Contingencies (20 %)	20,000
Total Construction Cost	$125,000
Planning, Engineering and Design	65,000
Construction Management	10,000
TOTAL FIRST COST	$200,000

The cost to provide one to two cubic feet per second of municipal water to augment flow would range from about $ 350 to 700 per day. This is based on a municipal wholesale rate of approximately $ 500 per million gallons of water, and excludes any costs for facilities to convey this water to the river. Although the cost of these facilities was not developed, they should be less than $25,000, including planning and design, if the water source is located close to the river.

Maintaining higher dissolved oxygen levels would reduce release of phosphorus, metals, and hydrogen sulfide from sediments. The severity of algal blooms could also be reduced if source controls are used in conjunction with this plan to control nutrient loading. High levels of contaminants would remain in river sediments and continue to pose a threat to aquatic life.

Since use of well water to augment flow could lower groundwater levels, and lower water levels can impact wooden piles, any well field should be located in an area free from buildings supported by wooden piles. However, if it was necessary to locate a well field near buildings with wooden piles, calculations should be made to determine if the required pumping rates could be maintained without creating a significant drawdown in the vicinity of these structures. In addition, a program to monitor drawdown of the water table over an appropriate area should be implemented during pumping to ensure that the integrity of these wooden piles would not be threatened. Impacts on groundwater level would likely be greatest in dry years when flow augmentation was needed the most. Augmentation using well water would require a well house, pump, and discharge structure. Care would be needed to site facilities so that adverse effects on historic resources and aesthetics were avoided.

Use of municipal water to augment flow would avoid potential groundwater impacts and could likely be accomplished without any new above ground structures. Use of this option might be limited, however, during dry years when reservoir levels were low.

Remove Contaminated Sediments.

Dredging sediments, perhaps the most desired solution to water quality and habitat problems, will provide dramatic short term improvement. A major benefit would occur as the source of high benthic oxygen demand is eliminated. However, sediment will again accumulate unless progress is made to eliminate pollutants at their source. Any large scale dredging project would also involve the removal of a large percentage of Phragmites stands as most of them are growing in riverside sediments.

All sediment removal estimates were developed using an all inclusive cost (both engineering and construction) of $100 per cubic yard for material that can be disposed of at Massachusetts landfills and $700 per cubic yard for sediments that must be disposed of out of state. These unit prices were based on coordination with an in-state landfill operator, and on information developed by Anderson-Nichols and Company, Inc. as part of their study of the Muddy River Conduit. It was also assumed that materialthat could not be disposed of at a Massachusetts landfill would be accepted at a facility in Maine. Although other methods of disposal were not evaluated and evolving technologies could impact disposal costs, it is felt that this represents the most likely method of disposal.

To estimate a range of costs for various levels of dredging in the Back Bay Fens, two potential projects were evaluated. The first would involve dredging to establish a water depth of four feet and the second would include dredging most of the sediments from the river. These sediments extend to a depth of twelve feet in some areas. Based on previous reports, the dredging volume for these two plans is 40,000 and 150,000 cubic yards respectively. In addition, using recently obtained data concerning sediment quality, it is estimated that approximately one third of this material has total petroleum hydrocarbons exceeding 3,000 ppm and due to Massachusetts regulations, must be disposed of by transporting it to an out-of-state disposal area or by incineration. The remaining material can be placed in an in-state landfill after dewatering. The estimated cost of these dredging plans would be approximately $ 12 million and $ 45 million respectively. Due to the very high cost of removing all sediments, the costs of removing only those sediments that could be disposed of at an in-state landfill were estimated. These plans, which would remove about 26,800 and 100,000 cubic yards of material respectively, would have costs of about $ 2.7 million and $ 10 million.

Dredging the Riverway to a depth of four feet from Huntington Avenue to the entrance of the twin culverts leading to the Brookline Avenue Gate House would involve the removal of about 25,000 cubic yards of material. In addition, based on the need to remove at least three feet of sediment from an area of about two acres at the northern end of Leverett Pond, an additional 10,000 cubic yards of material would need to be removed. This results in a total volume of about 35,000 cubic yards. Sediment testing in this area has determined that about one half of the Riverway sediment would fail to meet in-state disposal requirements and would have to be trucked to an out-of-state facility or incinerated. However, Leverett Pond sediments are coarse grained and would probably meet in-state disposal requirements. Accordingly, the total cost of removing and disposing this sediment is estimated at about $11 million. The cost of removing only those sediments that could be disposed of at in-state facilities was also estimated. Based on removing about 22,500 cubic yards of sediment, this plan has an estimated cost of about $ 2.3 million.

Removing all or most of the accumulated sediments from the Back Bay Fens would improve water quality by reducing sediment oxygen demand, nutrient availability, and growth of algal mats. Extent of improvement is difficult to predict, and would depend largely on the amount of dredging done, composition of resulting bottom sediments, and effectiveness of source controls to limit further nutrient loading. Although limited information is available regarding the probable composition of underlying sediments, these sediments probably have lower nutrient levels and oxygen demand than existing surficial sediments. Contaminant levels may also be lower. Further sediment testing would be needed to confirm this, however, and determine exactly how much dredging would be required to adequately improve water and sediment quality. If high contaminant levels were found in underlying sediments, capping with clean fill after limited dredging might be desirable. Increasing water depth to 6 feet or more should be sufficient to prevent development of algal mats. Blooms of free floating algae could still occur, however, if nutrient levels remained high. Elimination of the floating algal mats and odors produced by decaying vegetation would greatly improve the aesthetics of the area. Deepening the Fens would also improve fish habitat and allow for boating.

Dredging sediments from the Riverway would also be beneficial. As in the Back Bay Fens, the accumulated sediments have a high oxygen demand which contributes to low dissolved oxygen levels in the water. Restoring channel depth would improve fish habitat. More sediment testing would be required to assess the composition of underlying sediments and determine if dredging would substantially improve riverine conditions.

A major environmental dredging project in the Muddy River would also likely involve removal of about 5.3 acres of Phragmites from the Back Bay Fens and Riverway (see Appendix F). An additional several thousand square feet of cattail and other emergent vegetation would also be dredged.

Removal of the Phragmites would greatly improve aesthetics of the area. Some wildlife habitat cover value would be lost, however. This impact could be mitigated by planting cattail or other less obtrusive emergent species in suitable areas. Preserving or creating some shallow water/mudflat areas for wading bird habitat would also be desirable.

Phragmites stands in the Riverway probably improve Muddy River water quality by enhancing settling of suspended sediments and providing a substrate for organisms which remove dissolved nutrients from the water. Loss of Phragmites in the Riverway without implementation of source control measures could significantly degrade downstream water quality. Even with source control, it would be desirable to plant cattail in some locations along the Muddy River to promote continued biofiltration of Muddy River water before it enters the Back Bay Fens.

Adverse short-term dredging impacts include water quality degradation, loss of aquatic life, increased truck traffic, disruption of recreational use of the area, and poor aesthetics. All of these impacts are temporary, and would be outweighed by the benefits of improved water quality and Phragmites removal. These benefits would not be long-term, however, unless source controls are implemented.

<u>Phragmites Control Measures.</u>

As discussed under problem identification, expansion of Phragmites has degraded a large percentage of the riparian area along the Muddy River. The following paragraphs present alternative measures to eradicate existing stands and/or control future expansion.

Other than costs associated with removing Phragmites by dredging, which are based on the same cubic yard costs as those used for sediment removal, no costs for Phragmites control measures were developed as they were outside the scope of this study.

<u>Dredging</u> - Dredging would be an effective way to eradicate Phragmites from the Muddy River and Fens. Locations with standing water would need to be dredged to a depth of about 2 feet below the existing substrate to assure complete removal of Phragmites rhizomes. Removal of existing Phragmites from the Back Bay Fens and Riverway would require removal of about 18,000 cubic yards of sediment from an area of about 5.3 acres. Based on sediment testing within Phragmites stands, the majority of this material would likely be classified as solid waste (see Appendix D) and require disposal in a municipal landfill. However, sediment in the upper Riverway area near River Road was highly contaminated with petroleum hydrocarbons and must be transported to an out-of-state disposal area or incinerated. It is estimated that about 2,000 cubic yards of material would fall into this category. Using this sediment data, the total cost of this dredging is estimated at $ 3 million. Any Phragmites growing in adjacent upland areas could be eradicated by spot herbicide application. Following dredging, selective planting of cattail and other emergents would be beneficial to provide wildlife habitat and improve aesthetics. An aggressive long-term monitoring and control program would also be needed to prevent reinfestation.

Dredging has several disadvantages; it is the most expensive option and would have the greatest short-term adverse environmental impacts. These include short-term water quality degradation and the probable need to clear some riparian vegetation for construction access. One or more upland sites would also be needed as sites to dewater the sediments prior to disposal. Dredging operations would probably disrupt public use of the area to a greater extent than other control measures. On the positive side, dredging would provide water quality improvement due to concurrent removal of contaminated, nutrient rich sediments. Again, this improvement would only be temporary unless progress is made to eliminate pollution sources.

__Cutting__ - Repeated cutting can adequately control, but probably not eradicate, Phragmites. Cutting is particularly well suited when Phragmites is growing in relatively dry areas such as near the Victory Gardens in the Northern Basin. Cutting is much more difficult in standing water, but can be accomplished manually or using specialized equipment. Cutting in standing water in the Muddy River and Fens would be very difficult given the exceedingly soft nature of the sediments. Because new shoots can sprout from cut culms, collection and offsite disposal of the shoots is necessary.

Cutting would be most effective if done in late June or July when below ground energy reserves stored in rhizomes are at or near seasonal lows. Ideally, the initial cutting would be followed up a few weeks latter by a second cutting to further weaken the plants. An aggressive cutting regime practiced over a few years, should greatly reduce Phragmites growth, but would not assure eradication.

Cutting would be much less expensive than dredging, and would avoid most of the adverse impacts that dredging entails. Cutting alone would not likely eradicate Phragmites, however, and would need to be repeated indefinitely to provide adequate control. A long-term monitoring and control program would also be needed to locate and destroy new areas of growth.After stands are cut for a few years it might be possible to adequately control Phragmites biologically by planting cattail. Theoretically, cattail would be able to out compete, and possibly eliminate, the weakened Phragmites.

__Herbicides__ - Repeated application of Rodeo (a glyophosphate) can eradicate Phragmites. For relatively small stands such as those in the Riverway and Back Bay Fens, application using a backpack sprayer would be appropriate. Rodeo is most effective if applied after shoots have flowered and are actively trans-locating photosynthate to rhizomes. Repeat application the following year would probably be necessary for complete eradication. Following eradication, selective planting of cattail and other emergents would be beneficial to provide wildlife habitat and improve aesthetics.
A long-term monitoring and control program would be needed to prevent reinfestation.

Studies have shown that Rodeo is virtually non-toxic to aquatic life, does not bioconcentrate in fish tissues, and degrades quickly after application. Given this information, the degraded nature of the Muddy River, and the environmental benefits of Phragmites eradication, herbicide use in this case seems justified. Use of herbicides would also be much less costly than either dredging or cutting.

Selective Control - If complete eradication of Phragmites from the Muddy River using dredging or herbicides is not feasible, limited measures should be taken to control Phragmites growth and expansion. These include aggressive control of Phragmites in certain critical areas (such as near culvert entrances), eradication of small stands (less than 1000 square feet), control of lateral expansion of larger stands, and eradication of newly established stands. Control could be provided by cutting or herbicides.

It would be worthwhile to attempt to reduce lateral Phragmites expansion in some areas by planting cattail. Theoretically, competition by a well established cattail stand should be able to slow or prevent Phragmites expansion. It is noteworthy that little encroachment by Phragmites is occurring into adjacent cattail stands in the project area.

In general, the selective control and/or removal of Phragmites is recommended to improve riverine habitat and restore scenic vistas.

SECTION V

STUDY COORDINATION

Coordination efforts commenced in January 1992 with an announcement of initiation of the study and a field investigation of the Muddy River. This site inspection, which included officials from Boston and Brookline, provided Corps personnel the opportunity to view the river and discuss its water resource problems and needs.

As a result of study efforts that were either complete or underway by State and local governments, the Corps was able to review and utilize a large amount of existing information. To obtain the maximum coordination and cooperation with these and other involved agencies, an Inter-agency Working Group was formed. The purpose of this group was to meet on a periodic basis to share available information and discuss the status of our investigation. As the study progressed, this group was expanded to include citizens' groups and individuals interested in the study. The following is a list of agencies and groups that participated in these meetings:

- U. S. Environmental Protection Agency
- Commonwealth of Massachusetts
  - Department of Environmental Management
  - Department of Environmental Protection
- Metropolitan District Commission
- City of Boston
  - Parks and Recreation Department
  - Water and Sewer Commission
- Town of Brookline
  - Conservation Commission
  - Engineering/Transportation Department
- Citizens' Groups
  - Friends of the Muddy River
  - Restore Olmsted's Waterway (ROW)

In addition to the above coordination, a formal public meeting was held in the study area on June 24, 1992 to present the scope and status of the reconnaissance study. The meeting was well attended by both government officials and individuals, and provided a good opportunity for all interests to discuss the water resources needs of the watershed.

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SECTION IV

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

FINDINGS AND CONCLUSIONS

During the evaluation of flooding in the Muddy River watershed, all potentially feasible solutions to flood problems at identified damage zones were evaluated. This included upstream reservoirs and localized structural or nonstructural projects. These investigations determined that removal of restrictive culverts and channel improvements were the only viable solutions to potential flooding. Since detailed evaluation determined that the costs of these measures exceeded attributable flood damage reduction benefits, further study of these alternatives was not economically justified.

In addition to flooding, it was determined that the Muddy River suffers from severe degradation of the riverine environment. Problems include poor water quality, contaminated river bottom sediments and Phragmites expansion along a large percentage of the shoreline. As a result of these conditions, recreational and other usage of the parks that border the river has been heavily impacted. The fish population has also been affected and a public health advisory has been issued recommending that several species of fish from the Muddy River not be consumed.

To evaluate the above problems, a significant amount of data concerning water and sediment quality, and historic Phragmites expansion was developed and evaluated. These studies, presented in detail in the Appendices, resulted in the development of the following recommendations to improve environmental conditions within the watershed. Alternatives examined or formulated to improve water quality include source control, instream treatment, aeration and flow augmentation. Removal of contaminated sediments and Phragmites control would improve the overall riverine habitat and value. Figure 2 lists these alternatives and Federal, State, regional and local agencies that could be involved in further study or implementation. The Corps of Engineers is listed as being involved in possible further study of all identified solutions because the Fiscal Year 1993 Energy and Water Development Appropriations Act includes language directing feasibility phase study of the Muddy River. Accordingly, cost-shared feasibility studies could be initiated if desired by a qualified local sponsor. Within Massachusetts, State law stipulates that only the Commonwealth or one of its agencies may act as a local sponsor.

Figure 2

Environmental Improvement Alternatives / Involved Government Agencies	U.S. EPA	Corps (Study)*	MA (DEM, DEP, SHPO)	MWRA	MDC	City of Boston (Parks, Water & Sewer Environmental & Landmark Comm.)	Brookline (Conservation, DPW, Parks)
Water Quality Improvements							
Source Control							
Eliminate Sewer Connections	X	X	X	X		X	X
Best Management Practices		X			X	X	X
Instream Treatment	X**	X	X			X	X
Dissolved Oxygen Addition	X**	X	X			X	X
Flow Augmentation							
Divert Flow to Fens		X	X			X	
Addition of Municipal or Well Water		X	X			X	X
Remove Contaminated Sediments	X	X	X	X		X	X
Phragmites Control	X	X	X			X	X

Notes:

* Other than regulatory functions, further involvement by the Corps is presently limited to cost shared feasibility study.

** EPA involvement in these areas includes potential demonstration project funding

ENVIRONMENTAL ALTERNATIVES AND PRINCIPAL INVOLVED AGENCIES

RECOMMENDATIONS

As there are no economically justified flood damage reduction measures and anticipated flood flows along the majority of the river fail to meet minimum criteria established for Corps of Engineers involvement, no further Federal participation by the Corps of Engineers is recommended in the Muddy River watershed, Massachusetts.

It is suggested, however, that State and local officials consider the water resource related environmental problems and potential solutions identified in this report. This information should be used as a basis for any further study of measures to improve the water quality and riverine habitat of the Muddy River.

22 DEC 92

Date

BRINK P. MILLER
Colonel, Corps of Engineers
Division Engineer

APPENDIX A

PERTINENT CORRESPONDENCE

FRIENDS of the MUDDY RIVER
BROOKLINE-BOSTON

107 Queensberry Street
Boston, Mass. 02215-4748

22 Bowker Street
Brookline, Mass. 02146

telephone (617) 734-2741

Colonel Philip Harris
Commander, New Eng. Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02254

Attention: Director of Planning

Dear Colonel Harris:

We are naturally delighted at the prospect of the Corps undertaking to study and improve the Muddy River. The condition of the water has been a major concern since our organization was founded in September 1980. However we write primarily to urge you to address the serious flooding problem which exists all along the river. As part of the MEPA process for the Sears Roebuck development proposal an environmental engineer researched this problem for us. He relied primarily on your own 1968 report on the 1955 flood, Interim Report on Charles River for Flood Control and Navigation, Lower Charles River. He had discussions at that time with Mike Keegan of your staff as well as FEMA.

We know you can appreciate that private citizens and homeowners do not understand the implications of the silting and obstruction of the waterway in terms of the potential for property damage to their homes and businesses. We believe that the present obstructed situation of the Muddy River has the potential for causing millions of dollars worth of damage. The large scale redevelopment of the Sears Roebuck property as well as the ongoing intensification of of development in the medical area compounds the problem. We are told that others have urged you to undertake the first phase recommendations of the Metcalf & Eddy Water Quality Improvement Report as your initial effort. We disagree. It seems to us that the correction of illegal cross connections between the sewer and storm water systems, and the installation of gross particle separators are properly the responsibility of the municipalities--Boston and Brookline.

We look forward to the restoration of the river under the Sears Roebuck parking lot, and the time when the water will flow freely from Jamaica Pond through the Muddy River and the Fens to Charlesgate and the Charles River and ultimately the harbor. These decisions and the scope of work are in your hands. We would like to do anything possible to support your efforts. This undertaking means a lot to a lot of people.

Best Wishes,

Isabella M. Callanan

Isabella M. Callanan, President
Friends of the Muddy River

P.S. We enclose copies of our letters of comment on Sears Roebuck. We made copies of your 1968 report and sent one to Boston Water and Sewer.

JOHN R. ELWOOD, P.E.
83 KAREN ROAD
FRAMINGHAM, MASSACHUSETTS 01701

October 17, 1991

Michael Keegan, Chief
Basin Management Division
N.E. Division, U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

Dear Mr. Keegan:

I have the permission of the Friends of the Muddy River to send you the enclosed copy of a report on the Muddy River which I recently prepared for them. It is basically an overview and my own assessment of the situation.

Isabella Callanan has asked me to be their technical representative for the Corps study and I look forward to working with you on it.

Sincerely,

Jack Elwood

John R. Elwood

cc: Isabella Callanan

John R. Elwood
Environmental Engineer
83 Karen Road
Framingham, Massachusetts 01701

September 5, 1991

Isabella M. Callanan, President
Friends of the Muddy River
22 Bowker Street
Brookline, MA 02146

Re: Report to the Friends of the Muddy River

Dear Ms. Callanan:

Enclosed are three copies of a report I have prepared to summarize my work for the Friends of the Muddy River over the past few months. I have focussed particularly on water quality improvement in the Muddy River and I have attempted to make an assessment of the current situation based upon my review of several recent technical reports and contacts with the several key agencies involved in restoration of the Muddy River.

My intent, also, was to update you on recent developments and to identify some of the key people involved. I think I have also made these people aware of the continuing concern about these activities by the Friends of the Muddy River.

There are two particular activities that your group should stay on top of:

o The Corps of Engineers study which will start this Fall. They plan to have a kickoff meeting involving other agencies and groups. Contact person is Bill Hubbard (617-647-8552).

o The EPA Storm Water Discharge Permit program. Contact person is Jay Brolin (617-565-3590).

I have initiated a literature review of in-stream flow recycling and treatment to determine where this approach may have been used successfully elsewhere and I will continue this effort on my own.

I have reserved some time for participation in the Corps study planning meeting and I would also be pleased to make a presentation to your membership or Board if you desire.

Sincerely,

Jack Elwood

John R. Elwood

REPORT TO THE FRIENDS OF THE MUDDY RIVER

by

John R. Elwood, Environmental Engineer

September 5, 1991

I. TECHNICAL REPORTS REVIEWED

Muddy River Water Quality Improvement Plan, Metcalf & Eddy, September, 1990

Tannery Brook Storm Drain Investigation, Camp, Dresser & McKee. April, 1989

Emerald Necklace Master Plan(Draft), Mass Department of Environmental Management, October, 1988.

Hydrochemical Study of Pollution in the Muddy River, Boston University Department of Geology, 1991.

Selected Water Pollution Issues: New Federal Storm Water Regulations, Non-Point Source Pollution, Recent MWRA Initiatives. Boston Bar Association Legal Education Seminar, February 21, 1991

EPA 40 CFR 122,123 & 124; NPDES Permit Application Regulations for Storm Water Discharges (Federal Register November 16, 1990)

II. AGENCIES AND PERSONS CONTACTED

MASS Department of Environmental Protection:

Boston Office	Steve Lipman, Bost. Harbor Coord.	617-292-5673
NE Regional Office	Bill Gaughan, Act. Director	617-935-2160
	Sabin Lord, Reg. Environ.Engr	"
Westboro Office	Paul Hogan, WQ Manage.Planning	617-366-9181

U.S. Corps of Engineers -	Joe Ignazio, Ch. of Planning	617-647-8508
	Bill Hubbard, Environ. Plan.	617-647-8552
Brookline Conservation Comm. -	Ed Stashko, Coord.	617-730-2088
Boston Water & Sewer Comm. -	John Sullivan, Ch.Engr	617-330-9400
	Libby Blank, Engrg	"
	Tom Daly, Engrg	"
U.S. Environ. Protection Agcy -	Bill Butler, Wat.Qual.Br.	617-565-3538
	Jay Brolin, Permits	617-565-5590
Metcalf & Eddy -	Dave Bingham, Project Engr	617-246-5200
Northeastern University -	Fred Blanck, Civil Engr Dept	617-437-2444
MASS Dept of Environ. Manag. -	Patrice Kish, HLP Prog.	617-727-3160

III. ASSESSMENT AND RECOMMENDATIONS

Sanitary Sewer Cross-connections - This remains the most pervasive problem affecting water quality particularly from the Village Brook, Longwood Avenue and Tannery Brook storm drains. The Town of Brookline has an on-going effort toward eliminating sanitary sewage flows into Tannery Brook but, to date, no work has been done to eliminate them in the other two drains. Detailed surveys similar to the CDM investigation on the Tannery Brook drain are also necessary on these drains.

The Boston Water & Sewer Commission feels that it has eliminated all known cross-connections from its storm drains that discharge into the Muddy River or into Brookline drains which do so., including the Daisy Field drain and the upper end of Village Brook drain. They currently have a project out for bid to replace the Fenwood Street drain with a larger conduit. They feel that will eliminate overflows from the Francis Street siphon. They are also installing a gross particle separator in this line as a demonstration of this device.

As far as I am able to determine, there are no on-going enforcement proceedings either by EPA or the State(DEP or A/G's office) relating to pollution of the Muddy River by illicit sanitary discharges to storm drains.

Storm water runoff - Storm water runoff is probably the next most serious problem and, unfortunately, elimination of pollution from this source will be a long and expensive process requiring the implementation of best management practices, street sweeping, etc. I think it important to realize that the river itself, particularly the impoundments, play a role in storm water treatment and this aspect needs to be exploited. More about this later.

The best hope for getting action the storm water pollution problem lies in the direction of EPA's new storm water discharge permit program. This program could also provide a mechanism for the elimination of the remaining sanitary sewer cross-connections. Although the initial permitting phase is directed toward large systems, generally with populations over 250,000, it appears that, where other municipal systems are interconnected to the larger system, they will be included. BWSC is in the process of preparing Part I of the storm water permit application process, but it is not clear at this point how much of the Brookline system will be included. They are required to show drainage areas within one mile of the extremities of their system.

In-Stream Sediment - This, in my opinion, is the third most serious problem affecting water quality and probably will be the most expensive to rectify. A MDWPC research and demonstration project in the mid-1970's successfully removed and disposed of approximately 9,000 cubic yards of sediment from the Back Bay Fens employing a hydraulic dredge and an on-shore degritting plant. Since the sediment will now most likely be classified as a hazardous material, removal and disposal will be very costly. The sampling and analysis program recommended by M&E is necessary to fully define the disposal problem. Not removing the sediments would not be a total disaster since, once the pollution load on the river is reduced, they will self-cleanse to a degree over a period of time. In any event, I do not recommend dredging Ward's Pond since it would be too disruptive of the pond's ecosystem and the sediment appears to be more the result of the natural eutrophication and erosion process rather than from street runoff.

Flow Augmentation - The Muddy River suffers badly from low stream flow during dry periods due to lack of any appreciable upland storage such as wetlands and due to the large fraction of paved area in the drainage area. Several methods of flow augmentation have been proposed over the years, including the recyling of Charles River water through the Fens, diversion of clean water flow from the Stony Brook Conduit and diversions from some local water bodies in Brookline. All of the proposed schemes have some major problems associated with them and all would have difficulty surviving the environmental review process. Diversion of the Muddy River itself through the Back Bay Fens makes a lot of sense and should certainly be pursued. I believe that in-stream recycling, including some reoxygenation and possibly treatment such as sand filtration, is a more feasible option for the Muddy River upstream of the Brookline Avenue gatehouse.

RECOMMENDATIONS

o Work to get sanitary sewer cross-connection surveys implemented on the Longwood Avenue and Village Brook storm drains either by the Town of Brookline DPW or by the BWSC under their storm water discharge permit program.

o Support Corps of Engineer efforts in flood control work and sediment dredging. I believe the Corps is the only agency that has the capability and, at least the potential for the financial resources to deal with these major problems.

o Develop a continuing water quality monitoring and surveillance program with DEP that includes a role for the Friends of the Muddy River.

o Investigate the feasibility of flow augmentation through in-stream recyling and investigate the possibility of obtaining a research and demonstration grant from DEP and/or EPA for this purpose. Streamflow recycling could be accomplished simply and unobtrusively through the use of a submersible pump and a force main installed in the stream bed and connected to a cascade aeration device. If a treatment process, such as a pressure sand filter, were added the system could be an aid to cleaning up contaminated sediments.

Boston

Raymond L. Flynn, Mayor

November 20, 1991

Colonel Philip R. Harris
Division Engineer
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

RE: Muddy River
Improvement Project

Dear Colonel Harris:

We are looking forward to the start of the Army Corps' reconnaisance study of the Muddy River's issues and needs. We appreciate the leadership, professionalism, and sensitivity your agency brings to such investigations.

At the recent ceremony announcing funding for the Muddy River Improvement Project, you, Mr. William Hubbard of your staff, and Boston Parks Assistant Commissioner Victoria Williams had a discussion on the participation of the Boston Parks and Recreation Department in the reconnaisance study. I write to confirm this Department's commitment to be a full participant on the study's Technical Advisory Committee. We will strive for a close working relationship with you to insure the success of the study and any future projects that may result from its findings.

The fact that publicly accessible parklands of nationally historic significance line its banks for almost its entire length, from Jamaica Pond to Charlesgate, makes this at once a challenging yet promising opportunity for water resource planning and engineering. Public access, historic park landscape preservation, and recreation are critical values for both evaluating the Muddy River's problems and suggesting solutions. These critical values drive the Emerald Necklace Master Plan (ENMP). We are forwarding under separate cover a copy of the draft document for your staff's review. This plan is a collaboration between the Massachusetts Department of Environmental Management and the Boston Parks and Recreation Department. Providing background for your study, the ENMP is illustrative of the extensive work done to address the land-based issues of this system. We believe that consistency with this plan should be one of the criteria for evaluating the study's alternatives.

Boston Parks will bring to the deliberations of the Technical Advisory Committee a consistent and comprehensive interest in the Muddy River. This derives from being both the designated lead agency for implementation of the Master Plan, and the agency with jurisdiction for the vast majority of land along the Muddy River's banks.

Our expertise may prove particularly valuable to tap when you begin to organize the Citizens Advisory Committee. During the ENMP, we achieved the successful coordination of public process with constituent groups and public agencies. Your staff may wish to use us as the primary agency to consult in developing and managing your public process.

As your staff plans strategy and process for this study, they should feel free to contact my staff to ask questions or to arrange a meeting. Assistant Commissioner Victoria Williams (617 725-4505 x6213) will be my staff contact for this project.

Respectfully,

Lawrence Dwyer

Lawrence A. Dwyer
Commissioner

1293Y
cc: Asst. Commissioner Victoria Williams
Michael Keegan, U.S. Army Corps of Engineers

Restore Olmsted's Waterway

5 February 92

Dear Friend:

On behalf of ROW Coalition, it gives me great pleasure to invite you to participate in the EMERALD NECKLACE RIVERFEST.

The RIVERFEST will take place on Sunday, April 26th, 10 AM - 4 PM, along the Muddy River — from Jamaica Pond and Leverett Pond to the Riverway and the Fenway. The Riverway and the Fenway will be the two primary areas of activity.

The RIVERFEST is designed to be a celebration — a salute to the river and surrounding parklands, and to the remarkable community of individuals, institutions, and neighborhoods which inhabit the shores of this precious natural and recreational resource.

You can participate in a number of ways. First, we have enclosed a preliminary "Events and Activities" list to provide you with an idea of what is being planned. If you or your organization are interested in finding out about cosponsoring one or more of the activities shown, please place a check next to that activity and return the form. We will call you and explain what's expected of cosponsors. *Please* feel free to to come up with your own activity ideas. This list of events is just meant to start people thinking.

Second, a limited amount of booth space will be available for exhibits and displays, so please call or write us early and tell us what you need.

Finally, we need volunteers to work on one of several RIVERFEST organizing committees and on the day of the event. A few hours a month will go a long way toward making the festival a success. And please tell others. The RIVERFEST is for anyone who has ever enjoyed these magnificent parks and wants them to improve over time.

Please give us a call at 354-2094 or write to ROW at the address below.

RESTORE OLMSTED'S WATERWAY

Alison Leary
Festival Coordinator

Ed Shoucair
ROW Chair

163 Kent Street . Brookline MA 02146 . 617 731 1341

Frederick Law Olmsted

Brother, can you spare some time?

We need volunteers for an important job.

In 1880, Frederick Law Olmsted, architect of New York City's Central Park, designed the Boston Park System. Today it is known as the "Emerald Necklace," and it contains some of the most beautiful parks in America.

On Sunday, April 26th, there's going to be a celebration of the Emerald Necklace and Muddy River. Volunteers are needed now to help organize the event.

The success of the RIVERFEST depends on the support of individuals and organizations along the Muddy River and Emerald Necklace. Please help today.

We need:

- volunteers to work on committees
- organizations to sponsor RIVERFEST events
- musicians and other artists to perform
- restaurants to set up food booths
- financial contributions to cover expenses

Events will take place all along the Muddy River -- from Jamaica Pond and Leverett Pond to the Riverway and the Fenway. The Riverway and Fenway will be the two primary areas of activity areas.

The EMERALD NECKLACE RIVERFEST is sponsored by the coalition "Restore Olmsted's Waterway" (ROW) and other organizations in Boston and Brookline.

Call 354 -2094

EMERALD NECKLACE RIVERFEST
Sunday, April 26th

The EMERALD NECKLACE RIVERFEST is a Boston Earth Day Event

Boston
Raymond L. Flynn, Mayor

FOR IMMEDIATE RELEASE
May 27, 1992

CONTACT: Justine Liff
725 4505

COMMISSIONERS WALK OF THE EMERALD NECKLACE

On Friday, May 29, 1992, the Third Annual Commissioners Walk of the Emerald Necklace will begin at the Franklin Park Golf Clubhouse at NOON. The approximate schedule of the walk is as follows:

Noon	Franklin Park Golf Clubhouse
1	Arnold Arboretum Administration Building
1:45	Jamaica Pond Boathouse
2:15	Wards Pond
3:00	Olmsted Park
3:15	Muddy River
3:30	Sears Parking Lot
3:45	Back Bay Fens
4:00	Commonwealth Avenue Mall
4:30	Public Garden
End	Boston Common

Park Commissioners Herb Gleason, Charlie Titus, Bill Walzek, Victoria Williams, and Archie Williams will walk and talk with all interested citizens about projects and issues in the Emerald Necklace. Friends Groups for individual parks will meet the Commissioners along the way.

Issues of interest include funding of the Department of Environmental Management Olmsted Program, the Arnold Arboretum Master Plan, what to do about Pinebank on Jamaica Pond, the Army Corp of Engineer's study of the Muddy River, Sears Parking Lot, institutional participation in the care of Back Bay Fens, the control of dogs on Commonwealth Avenue Mall, the irrigation of the Public Garden, and a new tree fund on Boston Common.

Lunch will be provided at the Boathouse at Jamaica Pond. The Boston Park Rangers will be available to answer all questions and assist in helping participants who can only walk part of the proposed route.

For more information please call Justine Liff, Director of Planning and Development, Boston Parks and Recreation Department. 725-4505.

JOSEPH P. KENNEDY II
8TH DISTRICT, MASSACHUSETTS

COMMITTEE ON BANKING,
FINANCE AND URBAN AFFAIRS

SUBCOMMITTEES:
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EDUCATION, TRAINING AND EMPLOYMENT

SELECT COMMITTEE ON AGING
SUBCOMMITTEE ON HUMAN SERVICES

Congress of the United States
House of Representatives
Washington, DC 20515

1208 LONGWORTH BUILDING
WASHINGTON, DC 20515
(202) 225-5111

SUITE 605, THE SCHRAFFT CENTER
529 MAIN STREET
CHARLESTOWN, MA 02129
(617) 242-0200

June 23, 1992

James K. Hughes
Lieutenant Colonel
Corps of Engineers
Division Engineer
Department of the Army
424 Trapelo Road
Waltham, MA 02254-9149

Dear Lieutenant Colonel Hughes:

Thank you for the kind invitation to attend the meeting concerning your study of the flooding and related water resource needs of the Muddy River in Massachusetts.

I regret that I will be unable to attend because at the House of Representatives will be in session on Wednesday, June 24th. Jim Walsh, a member of my staff, will attend in my place.

Please accept my thanks again for thinking of me and best wishes.

Sincerely,

Joe Kennedy

Joseph P. Kennedy II
MEMBER OF CONGRESS

JPK/dc

All the best - Joe

City of Boston
The Environment
Department

Raymond L. Flynn
Mayor

Lorraine M. Downey
Director

Boston City Hall/Room 805
Boston, Massachusetts 02201
617/725-4416 or 725-3850

June 26, 1992

Mr. Richard Heidebrecht
US Army Corps of Engineers
Planning Directorate
424 Trapelo Road
Waltham, MA 02254-9149

RE: USCOE Water Resource Needs Study for Muddy River Watershed

Dear Mr. Heidebrecht:

The City of Boston Environment Department wishes to take this opportunity to respond to the recent request for comments relative to the ongoing USCOE study of water quality issues along the Muddy River and its floodplain.

The Environment Department has long been concerned with the degraded quality of vegetated wetlands along the River. <u>Phragmites</u> spp. dominate the vegetative communities along much of the River, to the exclusion of the more ecologically valuable <u>Typha</u> spp. and other species. The Boston Conservation Commission has traditionally been supportive of restoration projects which seek to allow replacement or partial replacement of Phragmites with more valuable vegetation.

To that end, the Environment Department would request that methods of improving water circulation in the Muddy River be studied. Dredging options should be considered, with an analysis of the extent of sediment contamination along the River. Disposal options should be evaluated for feasibility on environmental and economic grounds.

Increased flow in the Muddy River will produce many benefits, but it also produces the possibility that some sediments may be dislodged and carried downstream, out into the Charles River Basin. This potential impact, and methods to avoid it, also warrant discussion.

A major source of pollution in the River are the storm sewers which feed untreated wastewater directly into the system. This serves to significantly degrade the water quality in the Muddy River. The Environment Department has consistently advocated linking the Muddy River outfalls directly to the proposed Charles River CSO deep storage tunnel system, or otherwise diverting the untreated stormwater before it reaches the Muddy River system. It is hoped that the ongoing study can reopen this issue.

The ongoing study should also include discussion on "trouble spots" in the watershed which may be sources for contamination through drainage patterns. Special attention should be given to the Brookline D.P.W. yard, which it is believed is a source of petroleum contamination to Leverett Pond and downstream areas.

The Boston Environment Department is encouraged to see renewed attention being given to the Muddy River by the Corps of Engineers. It is our sincere hope that through a cooperative process involving municipal, state, and federal agencies, the River can be restored to a condition which allows for enjoyment by the public and derivation of ecological value by plant and animal communities.

We look forward to your continued interest in these issues, and welcome the opportunity to further participate in the study process.

Sincerely,

Lorraine M. Downey

Lorraine M. Downey
Director

LMD/AP:ap

The Commonwealth of Massachusetts
Executive Office of Health and Human Services
Department of Public Health
150 Tremont Street
Boston 02111

William F. Weld
Governor
David P. Forsberg
Secretary
David H. Mulligan
Commissioner

May 11, 1992

Robert Maietta
Department of Environmental Protection
Water Pollution Control Technical Services
P.O. Box 116
North Grafton, MA 01536

Dear Bob:

The following is an assessment of the potential adverse public health impact due to chemical concentration in Muddy River fish. These data were generated by your office due to a request from the Restore Olmsted's Waterway Coalition in Boston.

A total of fourteen samples were analyzed for eight metals. Cadmium, chromium nickel and lead were all below detection limits and although levels of arsenic, copper, mercury and zinc were detected, these were all below levels of public health concern.

All fourteen samples contained detectable levels of PCB Arochlor 1254 with seven samples at or higher than the FDA Action level of 2.0 mg/kg. The Environmental Protection Agency has classified PCBs as B2 carcinogens. Chemicals in this category are considered probable human carcinogens based on sufficient evidence of carcinogenicity in animals. The EPA has assigned a carcinogen potency factor (CPF) of 7.77 mg/kg/day. The CPF represents the excess lifetime risk due to a continuous constant lifetime exposure of one unit of carcinogen concentration. The CPF is an upper 95 percent confidence limit. Estimated intake values may be converted directly to incremental cancer risk by multiplication with the CPF.

As shown in the accompanying table, the levels of risk associated with PCB levels in the sampled species are in excess of acceptable risk levels for the Department of Public Health (MDPH). Consequently the MDPH will issue a Public Health Advisory for the consumption of Muddy River fish as follows:

- People should refrain from eating all common carp, brown bullhead and American eel from the Muddy River.

- Consumption of all other fish species from the Muddy River should be limited to two meals per month per person.

- Pregnant women and nursing mothers should not eat any fish from the Muddy River in order to prevent exposure of developing fetuses and infants to PCBs.

The Public Health Advisory is enclosed. If you have any questions, please call myself or Jessica Graham at 727-7170.

Sincerely,

Ngozi T. Oleru, Ph.D.
Chief of Toxicology
Bureau of Environmental
Health Assessment

NTO/tp

cc: Suzanne Condon, DPH
Jessica Graham, DPH
Mark Tisa, DFW
Mike Hutchison, DEP-ORS
Ed Shoucair, Restore Olmsted's Waterway, JP
Louise Hamilton, City of Boston, Health & Hospitals

Muddy River
Predicted Contribution of PCB to Cancer Risk
From Ingestion of Muddy River Fish

Species	Concentration Ave. (mg/kg)	Max. (mg/kg)	Most Likely Life Time* Exposure (mg/kg/day)	CPF (mg/kg/day)	Cancer Risk	Worst Case Life Time* Exposure (mg/kg/day)	Cancer Risk
C	2.02	3.8	1.11E-05	7.7	8.58E-05	7.05E-05	5.43E-04
BB	0.91	2.1	5.02E-06	7.7	3.87E-05	3.90E-05	3.00E-04
LMB	0.56	0.56	3.09E-06	7.7	2.38E-05	1.04E-05	8.00E-05
AE	2.00	2.00	1.10E-05	7.7	8.50E-05	3.71E-05	2.86E-04
Average	1.37	2.12	7.57E-06	7.7	5.83E-05	3.92E-05	3.02E-04

Assumptions:
Consumption rate = Adult consumer of recreational fish in New England
Exposure duration = 3258 days for most likely case
10950 days for worst case
Diet Fraction = 20 % of dietary fish is from the Muddy River
Lifetime = 75 years
Source: EPA Exposure Factors Handbook, March, 1989. EPA/600/8-891-43.

The Commonwealth of Massachusetts
Executive Office of Health and Human Services
Department of Public Health
150 Tremont Street
Boston 02111

William F. Weld
Governor
David P. Forsberg
Secretary
David H. Mulligan
Commissioner

PUBLIC HEALTH ADVISORY: MUDDY RIVER FISH

The Department of Public Health has reviewed laboratory data generated by the Department of Environmental Protection from Muddy River Fish. Common carp, brown bullhead and American eel contain elevated levels of polychlorinated biphenyls (PCBs) above background and Federal Food and Drug Administration regulatory limit of 2.0 ppm for commercial fish.

PCBs were used extensively in the electrical industry until 1977, when their use was banned by the federal government due to concern about health effects. The primary health concern associated with long-term exposure to PCBs is the potential risk of cancer since these compounds have been shown to cause cancer in laboratory animals.

RECOMMENDATIONS

1. People should refrain from eating all common carp, brown bullhead and American eel from Muddy River.

2. Consumption of all other fish species from the Muddy River should be limited to two meals per month per person.

3. Pregnant women and nursing mothers should not eat ANY fish from the Muddy River in order to prevent exposure of developing fetuses and infants to PCBs.

April, 1992

tp

July 22, 1992

Richard Heidebrecht
U.S. Army Corps of Engineers
Planning Directorate
424 Trapelo Road
Waltham, MA 02254-9149

RE: Muddy River Flood Control and Water Resources, Boston and Brookline, MA.

Thank you for submitting information regarding the scope for a planning study of the flooding and related water resource needs of the Muddy River. Staff of the Massachusetts Historical Commission have reviewed the information and have the following comments.

A review of the Inventory of the Historic and Archaeological Assets of the Commonwealth indicates that the Muddy River is included in the Olmsted Park System Historic District, which is listed in the National Register of Historic Places. In addition, a prehistoric archaeological site (19-SF-47) appears to be in the study area.

The MHC requests the opportunity to review a more detailed description of the planning study scope, including a map of the area proposed for study, and any proposals currently being considered. It is extremely important that historic and archaeological resources, including historic landscapes, be considered as early as possible in the planning stages of a project in order to avoid and minimize effects to significant cultural resources. The MHC also requests that the Army Corps of Engineers include historic and archaeological resources in the proposed planning study. The MHC would be happy to assist in developing an appropriate scope for the cultural resources portion of the planning study.

These comments are offered to assist in compliance with Section 106 of the National Historic Preservation Act of 1966 as ammended (36 CFR 800). If you have any questions please feel free to contact Connie Crosby or Maureen Cavanaugh at this office.

Sincerely,

Judith B. McDonough

Judith B. McDonough
State Historic Preservation Officer
Executive Director
Massachusetts Historical Commission

xc: Boston Landmarks Commisssion
Brookline Historical Commission
Isabella Callahan, Friends of the Muddy River
Massachusetts Association of Olmsted Parks
Kate Atwood, ACE

United States Department of the Interior

TAKE PRIDE IN AMERICA

FISH AND WILDLIFE SERVICE
400 RALPH PILL MARKETPLACE
22 BRIDGE STREET
CONCORD, NEW HAMPSHIRE 03301-4901

September 23, 1992

Mr. Joseph Ignazio, Chief
Planning Directorate
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Ignazio:

This is in response to your September 4, 1992 letter requesting comments on the reconnaissance level study of the Muddy River in Boston, Massachusetts.

Based on our understanding of the present water resource planning protocol, a formal study cannot proceed beyond the reconnaissance study phase unless two important criteria are met. These include a favorable cost/benefit relationship for one or more alternatives and a local sponsor that will agree to cost share up to 50 percent of the study costs.

In our discussions with Mr. Richard Heidebrecht of your staff, we have learned that considerable uncertainty presently exists with respect to attainment of these requisite conditions in the foreseeable future. Given that the reconnaissance study may result in a recommendation that no further Federal participation is warranted, and that the opportunity still exists for participation in future studies should they occur, we do not plan to undertake any investigations of the Muddy River Basin at this time.

If conditions change and a formal study is undertaken after the reconnaissance study has been completed, we would review the study plan to determine an appropriate course of action at that time.

We appreciate your willingness to coordinate this reconnaissance phase of the Muddy River project with our office. Questions concerning this response should be directed to Mr. Vern Lang of this office at 603-225-1411.

Sincerely yours,

Gordon E. Beckett

Gordon E. Beckett
Supervisor
New England Field Offices

Boston Landmarks Commission

City of Boston
The Environment Department

Boston City Hall/Room 805
Boston, Massachusetts 02201
617/725-3850

October 6, 1992

Mr. Joseph L. Ignazio
Director of Planning
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Re: Reconnaissance Study of the Muddy River Flood Control and Water Resources Needs, Boston, Brookline, and Newton, MA

Dear Mr. Ignazio:

I am responding to the copy sent to me of the letter dated September 16, 1992 which was addressed to Ms. Judith McDonough, Massachusetts Historical Commission.

Please note first of all that the Boston Landmarks Ccommission has dual jurisdiction to review this project. First to comment on it as part of the 106 process since the Emerald Necklace Parks are listed on the National Register of Historic Places. Second to review the project under Chapter 772 which establishes the Boston Landmarks Commission, since the area of the study encompasses properties designated as Boston Landmarks. We therefore feel it is essential for you to receive our initial comments.

Copies of Boston Landmarks Standards and Criteria for Jamaica Pond, Olmsted Park, the Riverway, and the Back Bay Fens are enclosed for your information. Standards and Criteria guide Boston Landmarks Commission's required review of any proposed capital projects.

Our comments on your preliminary letter are broad. The Boston Landmarks Commission can support water quality improvement as long as the historic design intent and integrity of the landscape are reinforced by the project. The Commission could not support permanent measures such as the building of structures or altering of the watercourse which would intrude upon the historic integrity of park design. Please note that for our purposes we include the Muddy River within our use of the terms landscape and park design.

Given this framework we cite a couple of examples: Within the Standards and Criteria the Commission potentially could approve the return of the open waterway as it was built, in regard to the Sears parking lot and the southern Fens areas. It could approve dredging and phragmites removal as long as the original watercourse and its relationship to the surrounding landscape are maintained. It could approve elimination of cross connections and other point source pollution. In-stream treatment, low flow augmentation and other management practices would be reviewed in terms of their impact on the landscape: Rock filtration or the rotating biological contactor would not be approved by the Commission if such measures were deemed as intrusions which alter the landscape.

We encourage the Corps to meet with the Boston Landmarks Commission directly as you proceed to a further stage in the project. Please note that in light of the fact that the final report should be formally reviewed by the Boston Landmarks Commission, interim meetings are advised, at least at the staff level. For future reference please not that projects which come out of this study will also have to be reviewed by the Commission before they can be implemented.

Sincerely,

Ellen J. Lipsey

Ellen J. Lipsey
Executive Director

cc: Judith McDonough
Justine Liff

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Wayne F. MacCallum, *Director*

21 October 1992

Joseph Ignazio
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Re: Water Resources Study of the Muddy River
Boston, MA
NHESP File No. 92-662

Dear Mr. Ignazio:

Thank you for contacting the Natural Heritage and Endangered Species Program regarding rare species and ecologically significant natural communities in the vicinity of the Muddy River in Boston, as described in your letter of 31 August 1992.

At this time, we are aware of one rare fish within the Muddy River. We have record of the Threespine Stickleback (*Gasterosteus aculeatus*), which inhabits the spring-fed pool behind the MDC skating rink in Olmstead River Park. This pool drains into the Muddy River through Willow Pond between Ward and Leverett Ponds. This is the only population of Threespine Stickleback known to occur within the state. It also represents the southeastern-most freshwater form of this species in North America. The Threespine Stickleback is state-listed as Threatened pursuant to the Massachusetts Endangered Species Act (MGL c.131A) and its implementing regulations (321 CMR 10.00). In order to protect this rare species habitat, the flow of water from the Threespine Stickleback pond should not be increased by efforts to control flooding downstream of Leverett Pond.

Please note that this determination is based on the most recent information available in the Natural Heritage database, which is constantly being expanded and updated through ongoing research and inventory. Should new rare species information become available, this determination may be reconsidered.

Please contact me or Pat Huckery, Acting Environmental Reviewer, if you have any questions.

Sincerely,

Diane Lauber

Diane Lauber
Environmental Review Assistant

DL/dl

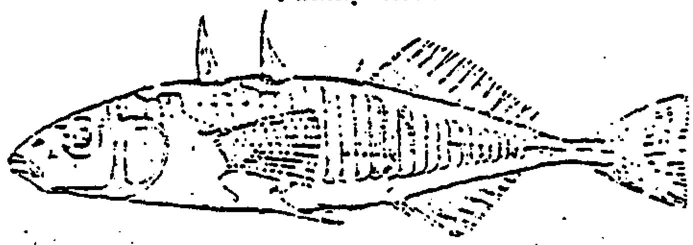
Natural Heritage & Endangered Species Program
100 Cambridge Street, Boston, MA 02202 (617) 727-9194, (617) 727-3151
An Agency of the Department of Fisheries, Wildlife & Environmental Law Enforcement

SPECIES INFORMATION

Scientific Name: *Gasterosteus aculeatus* Linnaeus

Order Gasterosteiformes
Family Gasterosteidae

Common Name: Threespine Stickleback



Distribution: Nearly circumpolar; widely distributed in the northern hemisphere. A salt and freshwater species. In North America from Chesapeake Bay north to Hudson Bay and Baffin Islands. Absent from arctic coasts of Northwest and Yukon Territories and Alaska, but occurs from Alaskan and British Columbian Pacific coast to lower California. In New England common in marine and estuarine waters but freshwater populations known only from a few locations in Maine and one location in Massachusetts.

Sources of Information:

Major Authorities:

Karsten Hartel, Curatorial Associate, Fish Department
Museum of Comparative Zoology, Harvard University

Dr. William H. Krueger, Associate Professor of Zoology
University of Rhode Island

Dr. Michael A. Bell, Assistant Professor, Ecology and Evolution Department
State University of New York at Stony Brook

Dr. James G. Hoff,
Southeastern Massachusetts University

APPENDIX B
HYDROLOGIC STUDY
MUDDY RIVER BASIN

BY
HYDROLOGIC ENGINEERING BRANCH
WATER CONTROL DIVISION
ENGINEERING DIRECTORATE

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS 02254-9149

NOVEMBER 1992

APPENDIX B
HYDROLOGIC STUDY
MUDDY RIVER BASIN

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APPENDIX B

HYDROLOGIC STUDY
MUDDY RIVER WATERSHED

1. PURPOSE

a. Background. This report presents a hydrologic investigation pertinent to the Muddy River Watershed. Included in the report is a description of the watershed, climatology, streamflow, analysis of floods, and flood frequency development. In addition, possible modifications and their effects on flood elevations are discussed.

b. Authority. Funds to conduct a reconnaissance study of the Muddy River were included in the fiscal year 1992 Energy and Water Appropriation Act and authority to conduct the study is contained in a Resolution, adopted September 12, 1969, by the Senate Committee on Public Works. Following is the stated Resolution:

> "That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby requested to review the report on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United Stated by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining the feasibility of providing water resource improvements for flood control, navigation and related purposes in Southeastern New England for those watersheds, streams and estuaries which drain into the Atlantic Ocean and its bays and sounds in the reach of the coastline of Massachusetts, Rhode Island and Connecticut southerly of, and not including, the Merrimack River in Massachusetts, to and including, the Pawcatuck River in Rhode Island and Connecticut, with due consideration for enhancing the economic growth and quality of the environment."

2. WATERSHED DESCRIPTION

a. General. The Muddy River watershed is located in the eastern part of Massachusetts in a highly urbanized area, within the town of Brookline, and cities of Newton and Boston. The Muddy River forms part of the "Emerald Necklace" Park, which is a carefully designed system of parks built by Frederick Law Olmstead in the late 1800s, to serve as a "green belt" surrounding the metropolitan area of Boston, and providing a number of attractions to residents of the area. Several outstanding institutions such as the Museum of Fine Arts, Longwood Medical Center, Emmanuel College, and others are located along the river. Most of the watershed is densely developed with very little open land available.

The Muddy River originates in Jamaica Pond and flows approximately 3.7 miles between the town of Brookline and the city of Boston. The normal elevation at Jamaica Pond is 60 feet NGVD; from there, the river drops to elevation 2.4 feet NGVD at its mouth at the confluence with the Charles River. Most of its fall (approximately 49 feet) occurs in the first half mile, from Jamaica Pond to Willow Pond. The lower portion of the river from Leverett Pond to its mouth, is very flat, dropping less than a foot per mile. The Muddy River's width varies between 25 and 40 feet. The river flows in a northerly direction through a series of small lakes, namely, Ward, Willow, and Leverett Ponds, and receives drainage from Brookline and Boston storm sewer outlets.

The area from Leverett Pond to upstream of Park Drive acts as a reservoir during high flow events. A 5,800-foot long dike and floodwall was constructed in 1965 by the Metropolitan District Commission (MDC) on the Brookline side of the river, it has a top elevation of approximately 14.3 feet NGVD. This dike was constructed after flooding was experienced in Brookline along the MBTA Mass Transit tracks in 1955 and 1962. It is considered that the dike helps somewhat to retain floodwaters within the river; however, it has many drain openings and no interior drainage facilities. Flooding behind the dike can be caused by local runoff unable to drain due to high stages or backflows from the Muddy River.

The outlet of the Muddy River at Park Drive consists of two 6-foot diameter conduits. The twin pipes convey flows from upstream of Park Drive into a 9 by 7-foot box conduit, then into another set of twin 6-foot diameter pipes, discharging upstream of Louis Pasteur Bridge in the Back Bay Fens. Midway through this drainage system, the Muddy River passes through a former gate house, which serves as a diversion structure that directs a portion of the flow into a conduit beneath Brookline Avenue (the Muddy River conduit). This conduit is made up of segments of varying sizes and conditions; however, in general it averages approximately 10 by 10 feet. The conduit is quite old (originally constructed in the late 1800s) and, therefore, is filled with sediments reported as high as 4 feet, resulting in an additional flow restriction. In addition to the relatively large 10 by 10-foot conduit, a pair of inverted siphons discharge flows under the Kenmore Square MBTA subway station. One siphon is a 6.5 by 6.5-foot box, the other is 3.3 by 4-foot box. The total flow area is 55.4 square feet. These siphons discharge into another large conduit section (11 by 9 feet), which discharges into the Charles River at Deerfield Street. Location of this conduit system is shown on plate 4 in the main report.

The flow that bypasses the diversion structure continues into the previously mentioned twin 6-foot diameter pipe system and discharges into the Back Bay Fens Park area. From here the river flows under a series of bridges and conduits, flowing under many major streets of the Boston area and also discharging into the Charles River. Originally, this area was saltwater marsh, fed by high tides from the Charles River. Due to construction of the original Charles River Dam in 1910, tidal flow into this area was precluded, resulting in this area becoming a fresh water system.

b. Tributaries to the Muddy River. The Muddy River has several principal tributaries. A description of the tributaries that represent about 90 percent of the drainage area above Park Drive, and the principal feature in the Back Bay Fens (Stony Brook overflow) follows. Tributaries are shown on the watershed map (plate 1) and pertinent information is listed in table 1. When delineating individual drainage areas much reliance was placed on elevations on the USGS topographic maps. For this reason drainage areas presented in this report may vary somewhat from previous studies. This could be attributable to storm sewers redirecting drainage in fringe areas. These drains however could become surcharged during major flood events with the resulting overland flow following the natural topography.

TABLE 1

TRIBUTARY INFORMATION

Name	Drainage Area (acres)	Drainage Area (sq. mi.)
UPPER WATERSHED		
Jamaica Pond	710.0	1.11*
Chestnut Street	164.0	0.26
Daisy Field	120.0	0.20
Village Brook	2,340.0	3.65
Tannery Brook	410.0	0.64
Huntington Avenue	260.0	0.40
Longwood Avenue	331.0	0.52
Local	215.0	0.33
Total Above Park Drive	4,550.0	7.11
LOWER WATERSHED (Back Bay Fens)		
Emmanuel College	400.0	0.62
Local	560.0	0.87
TOTAL DRAINAGE AREA	5,510.0	8.60

* Jamaica Pond area provides only a small contribution to floodflows due to its large surcharge storage capacity.

(1) <u>Sargent Pond/Jamaica Pond Area</u>. This area is located in the communities of Brookline and Boston. The principal flow course in this area originates in Sargent Pond at approximate elevation 75 feet NGVD. The brook flows in an easterly direction into Jamaica Pond, and falls approximately 15 feet in a stream distance of three-fourths of a mile for an average slope of 20 feet per mile. Development in the watershed consists mainly of residential and park areas, with the watershed estimated as 20 percent developed.

As stated previously, the Muddy River originates at Jamaica Pond, located in Boston which serves as a major recreation area, with a 64-acre water surface area. Total drainage area of the Sargent/Jamaica Pond system is 1.11 square miles. The 64-acre surface area of Jamaica Pond results in over an inch of runoff for every foot of storage above the normal water level. This, coupled with the small outlet size (18-inch pipe), results in very little contribution to floodflows.

(2) <u>Chestnut Street</u>. This tributary is located in the town of Brookline and has a total drainage area of 0.25 square mile. The principal flow course originates in Spring Pond at approximately elevation 100 feet NGVD. Flows from Spring Pond are in an easterly direction, discharging into Willow Pond, with an approximate fall of 20 feet in a stream distance of 1,500 feet for an average slope of 70 feet per mile. Development in the watershed is mainly residential and commercial, and the watershed is estimated to be 70 percent developed.

(3) <u>Daisy Field</u>. This watershed has a drainage area of 0.2 square miles and is located in the city of Boston. With a maximum elevation of 98 feet NGVD, the watershed drains into Leverett Pond, which has a normal water level of approximately 3.4 feet NGVD. Development in the watershed consists mainly of residential and recreational zones, with an estimated development of 80 percent. Like most of the tributaries within the Muddy River, the Daisy Field drainage system is almost 100 percent storm sewered.

(4) <u>Village Brook</u>. This tributary is located in the city of Newton and the town of Brookline, with contributing flows from the Chestnut Hill area and the city of Newton. This is the single largest tributary of the Muddy River and has a drainage area of 3.65 square miles. The principal flow course originates in Chestnut Hill Reservoir, 4 miles upstream of the Muddy River, at approximately elevation 131 feet NGVD. Flows are in an easterly direction, discharging into Leverett Pond. Development of the watershed is diverse, ranging from residences to a country club, and very dense urban development in the Village Square vicinity.

(5) <u>Tannery Brook</u>. This area is located in the town of Brookline and has a drainage area of 0.64 square miles. Flows from this watershed are in an easterly direction beginning at elevation 146 feet NGVD, and discharging into Muddy River downstream of Leverett Pond. Development is mainly residential and commercial, with the watershed estimated to be 90 percent developed.

(6) <u>Huntington Avenue</u>. This area has a total drainage area of 0.11 square miles and is located entirely in the city of Boston. Flows from this watershed begin at approximately elevation 50 feet NGVD, are in a westerly direction, and discharge into Muddy River upstream of Netherlands Road. Development is mainly residential, with the watershed estimated to be 50 percent developed.

(7) <u>Longwood Avenue and local drainage</u>. This area has a total drainage area of 0.52 square mile and is located in the town of Brookline. Flows from this watershed begin at approximately elevation 150 feet NGVD, and discharge into Muddy River downstream of Netherlands Road. Development is mainly residential and commercial, with the watershed estimated to be 50 percent developed.

(8) <u>Local</u>. The remaining small area along Muddy River (D.A. 0.33 square mile) is considered local drainage. Most of this area consists of residential development and is estimated to be 50 percent developed.

(9) <u>Emmanuel College</u>. This area is located in the city of Boston and has a total drainage area of 0.11 square mile. Flows from this watershed begin at approximately elevation 100 feet NGVD, and drain into Muddy River in the Back Bay Fens. Development in the watershed consists mainly of hospitals and residential, and the watershed is estimated to be 80 percent developed.

(10) <u>Back Bay Fens Local</u>. Local drainage in the Back Bay Fens is made up of small areas from downstream Park Drive to the Charles River. Total drainage area of this section is about 0.59 square mile. A major feature within the Fens is the Stony Brook overflow, and brief description follows.

(11) <u>Stony Brook Overflow</u>. Muddy River receives overflows from Stony Brook, located in the Back Bay Fens. With a 13.9-square mile drainage area, Stony Brook is an enclosed sewer system, beginning in Hyde Park and discharging flows into the Charles River. It was originally designed in the late 1800s to discharge into the Back Bay Fens Park area through two gate houses, Boston gate houses 1 and 2. However, due to contaminated discharges from Stony Brook, a foul flow conduit was constructed to divert flows directly into the Charles River. A system of sluice gates was installed to prevent normal flow from being discharged into the Back Bay Fens. When flood conditions occur and the water level in Stony Brook at gate house 1 rise above 13 feet NGVD, gates are operated and flows are diverted into the Fens area. It has been estimated that Stony Brook discharges into the Fens at an average of two to three times per month. At the present time, gates in house 2 are permanently closed, and the only discharge to the Fens is via gate house 1, which is operated by the city of Boston and maintained by the MDC.

3. CLIMATOLOGY

a. <u>General</u>. The Muddy River watershed has a variable climate and frequently experiences periods of heavy precipitation, produced by major storm systems and local thunderstorms. Recorded temperature extremes for Blue Hill and Boston stations, are shown in tables 2 and 3, respectively.

b. <u>Temperature</u>. The mean annual temperature in the Muddy River watershed is about 50 degrees. Recorded temperature extremes at representative stations within or adjacent to the watershed have varied from a maximum of 101 degrees Fahrenheit to a minimum of -21 degrees Fahrenheit at Blue Hill gage. Freezing temperatures may be expected from the latter part of September until late April.

c. <u>Precipitation</u>. Average annual precipitation and snowfall for the Blue Hill and Boston stations are shown in tables 2 and 3, respectively.

4. STREAMFLOW

There are no streamflow gages in the Muddy River, however, based on recorded streamflow data in the region, average annual streamflow can be expected to be about 1.7 to 1.8 cfs per square mile of drainage area. Total drainage area upstream of Park Drive (including Jamaica Pond) is 6.81 square miles, therefore, the average annual flow is expected to be 11 to 12 cfs.

5. FLOOD PROBLEMS IN THE MUDDY RIVER

Floods have been experienced along the Muddy River in the past, with the record event occurring in August 1955 and followed by another major flood in October 1962. These two events resulted in floodflows escaping the Muddy River channel and flowing down the MBTA Mass Transit tracks. Since these floods, the MDC has constructed a dike along the left bank of the Muddy River, which has effectively prevented a recurrence of this situation.

Hydraulic characteristics of the Muddy River that affect flood development are: (a) a relatively flat stream gradient averaging approximately 1.5 feet per mile, (b) localized restrictive channels and conduits, particularly in the vicinity of the Back Bay Fens Park area, (c) two 6-foot diameter pipes restricting outflow and allowing water to pond in the area above Park Drive, and (d) the previously mentioned dike along the left bank of the river with no interior drainage facilities.

Completion of the new Charles River Dam and pumping station by the Corps of Engineers in May 1978 has resulted in significant reduction in Charles River Basin flood levels thus preventing flooding caused by high Charles River stages particularly in the Back Bay Fens.

6. ANALYSIS OF FLOODS

a. <u>**General**</u>. Floods can occur any time of the year within the Muddy River watershed. The flood of record occurred as the result of hurricane "Diane" in August 1955, and the second largest resulted from the flood of October 1962. Lesser flooding occurred as a result of spring rainfall runoff conditions in March 1968. These floods were analyzed, along with synthetic flood events determined from rainfall values taken from Technical Paper No. 40 (TP-40), in an attempt to quantify flooding conditions.

(1) <u>**18-19 August 1955**</u>. Rainfall totals of approximately 12.7 inches for a 40-hour duration were recorded at Blue Hills Observatory and Boston Logan International Airport (two locations in close proximity to the Muddy River). This storm followed hurricane "Diane," which also produced considerable rainfall saturating the ground. The 18-19 August 1955 event is considered the flood of record in the Muddy River Watershed. Rainfall amounts and durations associated with this storm, compared to rainfall durations taken for TP-40, are shown in table 4. For the purpose of this study, this event was assigned a 1 percent chance of occurrence (100-year storm). Flood analysis computed a runoff of 7.3 inches.

TABLE 2
MONTHLY CLIMATOLOGICAL DATA
BLUE HILL MILTON, MASSACHUSETTS

	Temperature (f)			Snow (in)	Precipitation (in)		
	Mean	Max	Min	Mean Monthly	Mean	Max	Min
January	25	68	-16	15.4	4.32	11.61	0.89
February	25	68	-21	16.1	4.33	9.32	0.71
March	36	85	-5	11.2	4.60	10.96	0.06
April	50	94	6	3.1	4.22	10.37	1.38
May	60	93	27	0.1	3.90	9.16	0.62
June	69	99	36	0.0	3.22	13.73	0.71
July	76	100	44	0.0	3.56	11.82	0.13
August	73	101	39	0.0	4.26	18.78	0.53
September	67	99	39	0.0	3.84	11.04	0.69
October	55	88	21	0.2	4.06	10.84	1.31
November	43	81	5	2.8	4.99	9.78	0.55
December	26	72	-19	10.7	4.49	12.60	0.92
ANNUAL	50.5	101	-21	59.7	49.79	65.51	26.96

TABLE 3
MONTHLY CLIMATOLOGICAL DATA
BOSTON, MASSACHUSETTS

	Temperature (f)			Snow (in)	Precipitation (in)		
	Mean	Max	Min	Mean Monthly	Mean	Max	Min
January	29	63	-12	21.97	3.64	10.55	0.61
February	27	70	-4	29.59	3.39	7.81	0.72
March	38	81	6	6.91	3.82	11.00	0.59
April	50	94	16	0.96	3.69	9.46	1.24
May	59	95	34	0.02	3.29	13.38	0.25
June	70	100	45	0.00	3.32	13.20	0.48
July	77	102	50	0.00	3.05	11.69	0.52
August	75	102	47	0.00	3.44	17.09	0.83
September	68	100	38	0.00	3.08	10.94	0.22
October	56	90	28	0.00	3.14	8.68	0.06
November	46	78	15	4.54	3.99	8.89	0.64
December	29	73	-7	20.29	3.79	9.74	0.66
ANNUAL	52	102	-12	83.12	41.64	62.14	23.71

(2) **5-6 October 1962**. This was a high intensity coastal storm over the New England area with rainfall totalling 8.5 inches in a 53-hour duration recorded at Blue Hill and Boston Logan Airport stations. Rainfall-depth duration data for this storm is also shown in table 4. The 5-6 October 1962 storm was estimated to have a 2 percent chance of occurrence (50-year event). During flood analysis a total runoff of 4.2 inches was computed.

(3) **17-18 March 1968**. This storm, less severe than events previously mentioned, had a recorded rainfall of 4.8 inches and duration of 40 hours. For the purpose of this study, this event was assigned a 10 percent chance of occurrence (10-year event).

(4) **2-Year Storm**. A synthetic 2-year storm was developed from rainfall data from TP-40. Rainfall data from TP-40 can be seen in table 4.

TABLE 4
RAINFALL FREQUENCIES

	Time in Hours						
Storm	0.5	1	2	3	6	12	24
2-Year	0.95	1.2	1.55	1.8	2.25	2.7	3.2
10-Year	1.5	2.0	2.4	2.7	3.3	3.95	4.7
50-Year	1.9	2.5	3.10	3.4	4.3	5.2	6.1
100-Year	2.25	2.75	3.45	3.75	4.75	6.0	7.0
Aug 1955		1.8	3.2	4.3	6.5	7.8	8.8
Oct 1962		0.6	1.0	1.2	1.8	3.0	4.3

b. Analysis. Two computer models were used to evaluate flood conditions in the Muddy River. To compute the contrib- uting runoff on the upper portion of the river in the different drainage systems, the Storm Water Management Model (SWMM) was used, while in the lower portion of the river through the Back Bay Fens, the HEC-2 computer program was employed to develop water surface profiles. This was done because the area upstream of Park Drive acts like a reservoir with flood levels more a function of runoff volume with limited outflow through the 6-foot diameter pipes. Flood levels through the Fens are a function of high discharges from the Park Drive conduits and the Stony Brook overflows.

(1) SWMM Model Development Upstream Park Drive. The SWMM model, a comprehensive computer program which simulates urban runoff quantities in sewer systems, was used to analyze the area above Park Drive. For purposes of estimating runoff in the Muddy River Watershed, major tributaries or catchment areas were analyzed individually to determine their characteristics and runoff potential. In some cases individual areas were subdivided into subdrainage segments for better definition of runoff rates and volumes.

Flood hydrographs were computed for the 1955, 1962, 1968 and 2-year frequency storms using the "SWMM--Runoff Block" in each subcatchment area. Various infiltration rates were assumed along with appropriate friction Manning's "n" factors for the river and for the pipes. Impervious percentage varied depending upon the area. Slopes, pipe sizes and additional pertinent information from each subcatchment area were obtained from sewer plans provided by the city of Boston and the town of Brookline, USGS maps, aerial photographs provided by the Cartographic Information Research Services at UMass and surveyed mapping provided by the Commonwealth of Massachusetts, Department of Environmental Management. Table 5 shows pertinent hydrologic information for the sub-catchment areas.

Table 5

MUDDY RIVER RECONNAISSANCE STUDY
SWMM MODEL DEVELOPMENT
SUBCATCHMENT INFORMATION

Name	Number of Subcatchments	Pipe Size At Outlet (inches)	Impervious Percentage (%)
Sargent/Jamaica Pond	2	18	20
Chestnut Street	1	42 X 40	70
Daisy Field	1	24	80
Village Brook	4	108 X 144	80 max 10 min
Tannery Brook	3	80.5 X 90.5	90
Huntington Avenue	1	24	50
Longwood Avenue	1	60 X 66	50

The model was calibrated to the extent possible by attempting to reproduce the estimated total inflow hydrograph for the 1955 flood above Park Drive from COE Interim Report on Charles River May 1968. Once calibrated, the 1962 total inflow above Park Drive was checked for reasonableness. Then the other two flood events (March 1968 and 2-year) were analyzed. After runoff was calculated at each subcatchment, input flows were transported using the "SWMM--Transport Block" section of the model to simulate the main stem of the Muddy River.

Input hydrographs from each subcatchment area were combined at the mouth of Leverett Pond and a "SWMM--Reservoir Block" was used to route flows from Leverett Pond to the entrance of the twin 6-foot diameter twin conduits upstream of Park Drive. A stage-discharge rating curve was developed for the twin conduits. An area capacity curve was computed, based on 1-foot contour mapping and is shown on plate 2. This information was used to develop an elevation, storage, outflow relationship to conduct the reservoir routings. Flood hydrograph analysis for the four flood events are shown on plates 3, 4, and 5

(2) __Park Drive/Muddy River Conduits__. As mentioned in paragraph 2, this conduit system is very complex. The Muddy River first enters two 6-foot diameter reinforced concrete pipes for a length of about 535 feet. At this point, the pipes discharge into a former gate house/diversion structure, which allows for diversion into the Muddy River conduit. The diversion conduit flows a total distance of 3,415 feet beneath Brookline Avenue and Kenmore Square to discharge into the Charles River. Flows into the Muddy River conduit enter initially a 9 by 11-foot wood/concrete portion 70 feet long. This section is followed by a 10 by 10-foot concrete conduit, which is approximately 2,200 feet in length. The wood/concrete section continues for 300 feet and discharges flows into a 55.4-square foot siphon chamber containing two concrete siphons (6.5 by 6.5 feet and 3.3 by 4 feet, respectively), which convey flows under Kenmore Square. From this point, flows are discharged into a 9 by 11-foot wood/concrete section, flowing under Deerfield Street and Storrow Drive for 700 feet and discharging into the Charles River.

The city of Boston has conducted an extensive investigation of the conduit, including utilizing divers with video cameras. From these inspections, it has been concluded that the conduit has accumulated 3 to 4 feet of sediments. Also, inspection of the siphons under Kenmore Square indicate they are relatively clear of sediment/debris. The city of Boston is planning to replace the wooden sections of the Muddy River conduit in the near future.

The hydraulics of this system are very complex, making flood analysis difficult and quite uncertain. For purposes of this study, a discharge rating curve was computed for the Muddy River conduit, assuming a normal Charles River Basin elevation of 2.4 feet NGVD, the main section of the conduit with 4 feet of sediment, and the siphons relatively clean. A series of discharges were assumed and head losses were computed from the Charles River Basin to the diversion structure. This curve, along with rating curves for the remaining 6-foot diameter pipes, were used as a guide to estimate flow distribution through the system. From this analysis, estimated flow into the Muddy River conduit ranges from 220 to 180 cfs.

For flows that continue to the Back Bay Fens at the diversion structure, the Muddy River enters a 7 by 9-foot culvert for 160 feet before entering another set of twin 6- foot diameter pipes for a length of 240 feet. These pipes exit into an open channel upstream of Louis Pasteur Bridge. At Louis Pasteur Bridge, the river flows through another set of two 6-foot pipes with a length of 450 feet.

(3) __Back Bay Fens Park__. With the above analysis completed, flow through the Fens could be estimated. As mentioned previously, a major contributor (and major unknown) in this reach of river is the Stony Brook overflow, which occurs at Boston gate house 1. At this

gate house, four 6 by 13-foot gates can be opened, depending on flood levels in Stony Brook and the Muddy River. In the "Stony Brook System Analysis," by Frederick R. Harris, Inc," overflow was estimated for various flood events. Analysis of the 1955 flood along Stony Brook showed that approximately 1,170 cfs would be expected to be discharged into the Muddy River (reference i). This flow was used as a guide, and overflows for the 1962, 1968 and 2-year floods were estimated. Analysis for the August 1955, October 1962, March 1968, and 2-year flood events are graphically shown on plates 3, 4 and 5, respectively. These flows were combined with the remaining flow exiting the Park Drive conduits to develop flows for use in HEC-2. Computed flood profiles are shown in plates 6 and 7. Results for the four flood events are presented in table 6.

7. FLOOD FREQUENCIES

a. General. The Muddy River is a small but very complicated watershed. The area upstream of Park Drive acts as a reservoir with flood levels a function of volume of runoff and limited outlet capacity. The Back Bay Fens on the other hand, is controlled by restricted conduits/bridges. Major uncertainties concerning flood analysis within the Fens are: the amount of flows diverted into the Muddy River conduit, and more importantly, the magnitude of overflows from Stony Brook.

b. Upstream Park Drive. Analyzing the computed inflow hydrograph into the storage area above Park Drive, shows the 1955, 1962, and 1968 storms had computed peak flows of 1,840, 1,060 and 840 cfs, respectively. Total outflows for these same events are 680, 670, and 600 cfs, respectively. We note the very small increase in outflow is due to the limited capacity of the 6-foot diameter pipes at Park Drive. Major increases in stages above Park Drive do not result in significantly higher increases in outflow due to limited sizes of the pipes and effects of tailwater on pipe capacity.

Outflow from this area does not meet minimum Corps criteria as specified in ER 1165-2-21. However, after discussions with headquarters it was decided that NED should continue with the study. The resulting flood analyses associated with these storms, as well as the computed 2-year frequencies, were used to develop discharge and stage frequencies shown on figures 1 and 2, respectively. These stage frequencies represent existing conditions above Park Drive, and were used in flood damage studies.

c. Back Bay Fens. The assumed discharges from upstream of Park Drive flowing through the Fens (i.e., assumed flows that bypass the diversion structure) are in the order of 460 to 350 cfs. These flows were added to assumed Stony Brook overflows, resulting in estimated discharge frequencies shown below (assuming coincident Stony Brook and Muddy River peak flows). These flows were inputted into a HEC-2 backwater model. Cross section and bridge information were obtained from existing mapping and file drawings. Flood profiles were computed and two stage frequencies were developed; one at Agassiz Bridge, and one at Louis Pasteur Bridge as shown in figure 2.

TABLE 6

MUDDY RIVER RECONNAISSANCE STUDY
SUMMARY INFORMATION/EXISTING CONDITIONS

Storm	UPSTREAM PARK DRIVE			DOWNSTREAM L. PASTEUR BR.		UPSTREAM AGASSIZ BR.	
	Inflow (cfs)	Outflow* (cfs)	Water El. (ft, NGVD)	Outflow (cfs)	Water El. (ft, NGVD)	Outflow** (cfs)	Water El. (ft, NGVD)
August 1955	1,840	680	13.9	460	9.4	1,630	6.8
October 1962	1,060	670	10.2	450	8.4	1,340	5.9
March 1968	840	600	7.3	400	6.2	850	4.8
2-Yr. Event	620	500	5.9	320	5.0	600	3.8

* Total outflow includes flow through Muddy River Conduit
** Flow includes added inflow from Stony Brook Overflow

Frequency (%)	Event	Stony Brook Overflow (cfs)	Muddy River Flow (cfs)	Total Outflow (cfs)
1	100-Year	1,170	460	1,630
2	50-Year	890	450	1,340
10	10-Year	450	400	850
50	2-Year	280	320	600

8. FLOOD CONTROL IMPROVEMENTS

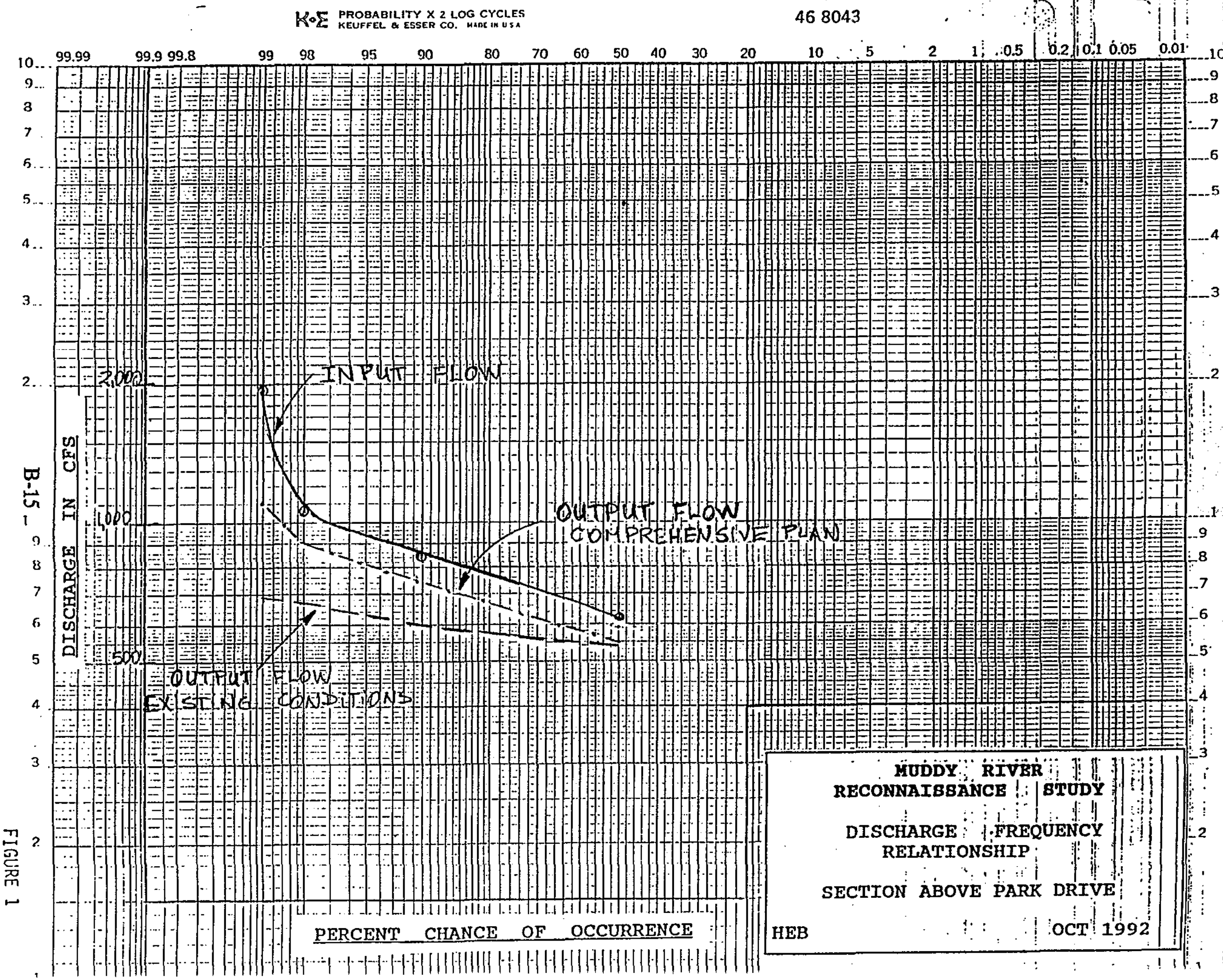
a. General. Various flood control options were investigated at a cursory level of detail. Options considered were flood control reservoirs and channel improvements and are described as follows.

b. Flood Control Reservoirs. Since the Muddy River watershed is located in a highly urbanized area, little land is available for a flood control reservoir. The major existing impoundment within the watershed is Jamaica Pond. Watershed analysis indicates outflow from this pond does not contribute significantly to downstream flooding. Modification to other existing ponds, in the interest of flood control, is not practical from an engineering or an economic point of view due to their limited storage capacity.

c. Channel Improvements

(1) General Analysis shows that potential flooding of the Muddy River above Park Drive can be expected due primarily to undersized pipes underneath the Sears Parking lot. Flooding in the Back Bay Fens is also a possibility, however, since construction of the new Charles River Dam potential flooding in this area has been significantly reduced. To achieve increased discharge capacity through the Park Drive conduit system, however, channel improvements through the Back Bay Fens are necessary. Two alternatives for flood control were analyzed. One alternative is termed a comprehensive plan, a second alternative is called the minimum plan.

(2) Comprehensive Plan This plan would involve replacing the twin 6-foot diameter pipes underneath the Sears Parking lot with a much larger conduit. Two options were considered in this plan. Option A considered the replacement of the entire length of conduit (535 feet) with a 10 by 20 - foot conduit. Option B considered the replacing the initial 200 feet of the culvert with a 10 X 20 - foot conduit followed by an open channel of equivalent capacity. This conduit/channel system would allow for significantly greater discharges to reach the Muddy River Conduit diversion structure thus enabling better utilization of the existing Muddy River conduit. In addition, in an attempt to maximize discharges through the Fens, several improvements were considered. The most significant improvement would involve replacing the two 6-foot diameter pipes leading to the Louis Pasteur Bridge with an



K•E PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8043
INPUT FLOW
OUTPUT FLOW
COMPREHENSIVE PLAN
OUTPUT FLOW
EXISTING CONDITIONS
DISCHARGE IN CFS
2,000
1,000
500
PERCENT CHANCE OF OCCURRENCE
MUDDY RIVER
RECONNAISSANCE STUDY
DISCHARGE FREQUENCY
RELATIONSHIP
SECTION ABOVE PARK DRIVE
HEB
OCT 1992

B-15

FIGURE 1

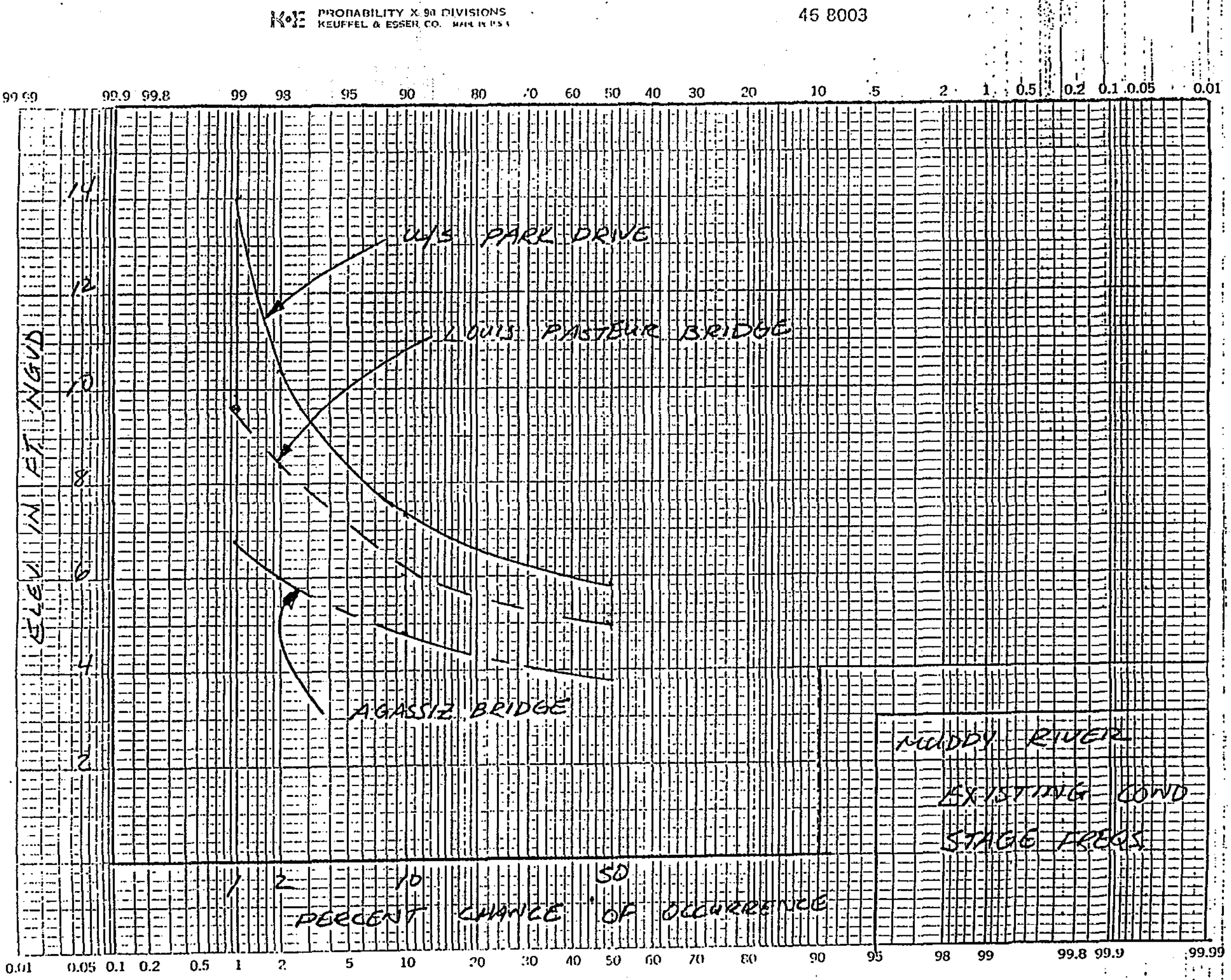

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO.
46 8003
W/S PARK DRIVE
LOUIS PASTEUR BRIDGE
AGASSIZ BRIDGE
ELEV. IN FT. NGVD
PERCENT CHANCE OF OCCURRENCE
MUDDY RIVER
EXISTING COND
STAGE FREQS

FIGURE 2

B-16

open channel with a 30 foot bottom width. This would be coupled with dredging the Muddy River channel to -4.0 feet NGVD and maintain a 30 foot bottom width from Boylston Street to Park Drive. These improvements will increase the hydraulic conveyance through the Fens and also lower the tailwater elevation (during flood events) at the Park Drive conduits. The comprehensive plan allows increased outflow from above Park Drive to be discharged through the Back Bay Fens without increasing flooding.

It is believed that this plan would maximize flows through the remaining twin 6-foot diameter conduit under Park Drive (by lowering the tailwater elevation) and allow for significant flows through the existing Muddy River conduit. In addition, if sediments are removed from the Muddy River conduit at some future date the proposed conduit leading to the diversion structure should have adequate capacity and not represent a restriction.

Flood routing for the events analyzed were conducted with a revised outlet rating curve representing improved conditions. The resulting modified output hydrographs for the storms analyzed, as well as additional information such as river stage elevations and output flow, are summarized in table 7, and revised stage frequencies are shown in figure 3. Improved condition flood analysis is graphically shown on plates 8 and 9.

(3) **Minimum Plan** Questions were raised as to a minimum plan which could be implemented and which may not have major impacts in the Fenway area. This alternative was determined to be the replacement of the twin conduits underneath the Sears Parking lot with conduits large enough to account for the existing capacity of the culverts downstream the gatehouse plus the estimated existing capacity of the Muddy River Conduit. Replacement of the conduit's deteriorated wood/concrete segments however, was assumed, since this is a requirement to insure the conduit's integrity and is already being contemplated by the City of Boston. Similar to the comprehensive plan, the minimum plan was further broken into two options. Option A would consider the replacement of the entire 535-foot length with a 10 X 15-foot conduit. A second option (Option B) considered the replacing of the conduit with a combination 200 feet of 10 X 15-foot conduit followed by an open channel 335 feet long. Both alternatives have the same hydraulic capacity.

Running the SWMM model with a revised outlet rating curve to reflect these conditions resulted in the 1 percent event output flow of 920 cfs and an elevation above Park Drive of 11.2 feet NGVD. Flows through the box culvert downstream of Park Drive were estimated to be between 300 to 500 cfs, while flows into the Muddy River conduit were estimated to be between 400 and 500 cfs. With the minimum plan and no flood control improvement at Louis Pasteur and the Back Bay Fens area it is believed that this alternative would not result in significant flow increase (over existing conditions) through the Back Bay Fens. This is a result of the restriction at Louis Pasteur Bridge which would remain under this scenario. This restriction causes a significant tailwater effect and reduced capacity at the Park Drive conduits. The major benefit of the minimal plan is to allow for better utilization of the Muddy River Conduit.

TABLE 7

MUDDY RIVER RECONNAISSANCE STUDY
SUMMARY INFORMATION/IMPROVED CONDITIONS

	UPSTREAM PARK DRIVE			DOWNSTREAM L. PASTEUR BR.		UPSTREAM AGASSIZ BR.	
Storm	Inflow (cfs)	Outflow* (cfs)	Water El. (ft, NGVD)	Outflow (cfs)	Water El. (ft, NGVD)	Outflow** (cfs)	Water El. (ft, NGVD)
August 1955	1,840	1,100	10.0	700	6.5	1,870	6.2
October 1962	1,060	850	6.4	520	5.5	1,410	5.3
March 1968	840	750	5.6	440	4.6	890	4.5
2-Yr. Event	617	550	4.7	350	3.6	630	3.5

* Total outflow includes flow through Muddy River Conduit
** Flow includes added inflow from Stony Brook Overflow

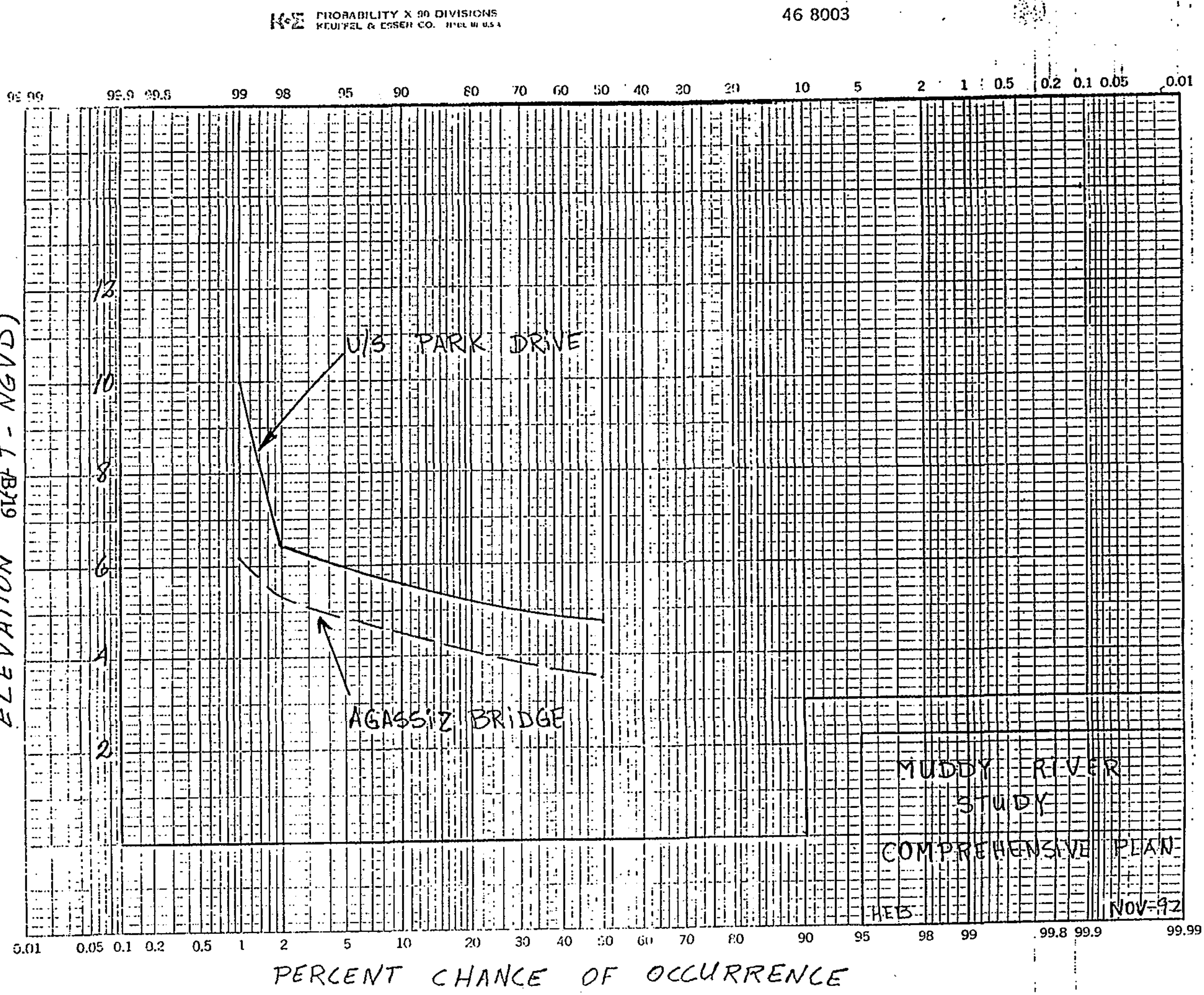

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO.
46 8003
U/S PARK DRIVE
AGASSIZ BRIDGE
ELEVATION (FT - NGVD)
PERCENT CHANCE OF OCCURRENCE
MUDDY RIVER STUDY
COMPREHENSIVE PLAN
HEB
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FIGURE 3

9. SUMMARY/CONCLUSION

From the computer simulation with improved condition Comprehensive Plan results, we conclude that this plan would solve flooding problems in the area above Park Drive and in the Back Bay Fens. Flood elevations upstream of Park Drive were reduced from 13.9 to 10.0 feet NGVD for the 1955 storm, which is considered having a 1 percent chance of occurrence. Analysis shows these improvements would effectively eliminate all major flooding for a 1 percent chance event.

10. REFERENCES

a. Preliminary Hydrologic Analysis of Muddy River, Charles River Basin COE, 14 June 1965.

b. 21 April 1966 COE Reconnaissance Study - Local Protection of the Muddy River.

c. May 1968 COE Interim report on Charles River for flood control and Navigation.

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e. Technical Paper No 40 "Rainfall Frequency Atlas of the United States: U.S. Department of Commerce

f. FEMA - "City of Boston Flood Insurance Study," November 2, 1990.

g. FEMA -"Town of Brookline Floodplain Maps," February 1977.

h. "Flow Augmentation of the Boston Back Bay Back Bay Fens Pond," C.E. Mcguire, Inc. - February 1977.

i. "Southwest Corridor Project - Stony Brook System Analysis," Frederick R. Harris, Inc., September 1979.

j. Storm Water Management Model - SWMM, Version 4.0, Gainsville, Florida, April 1987.

k. HEC-2, Water Surface Profiles - U.S. Army Corps of Engineers, Hydrologic Engineering Center, September 1990.

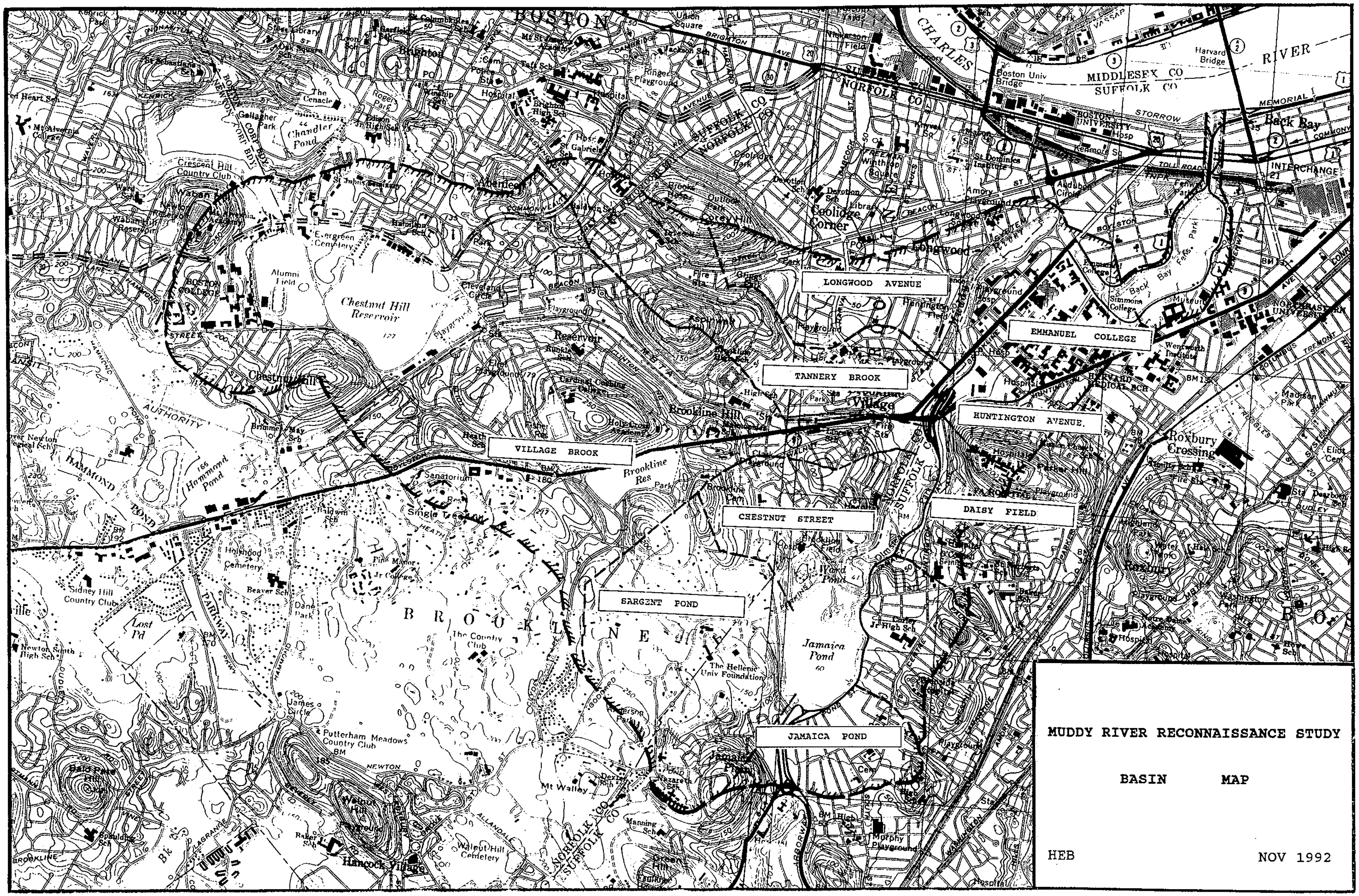
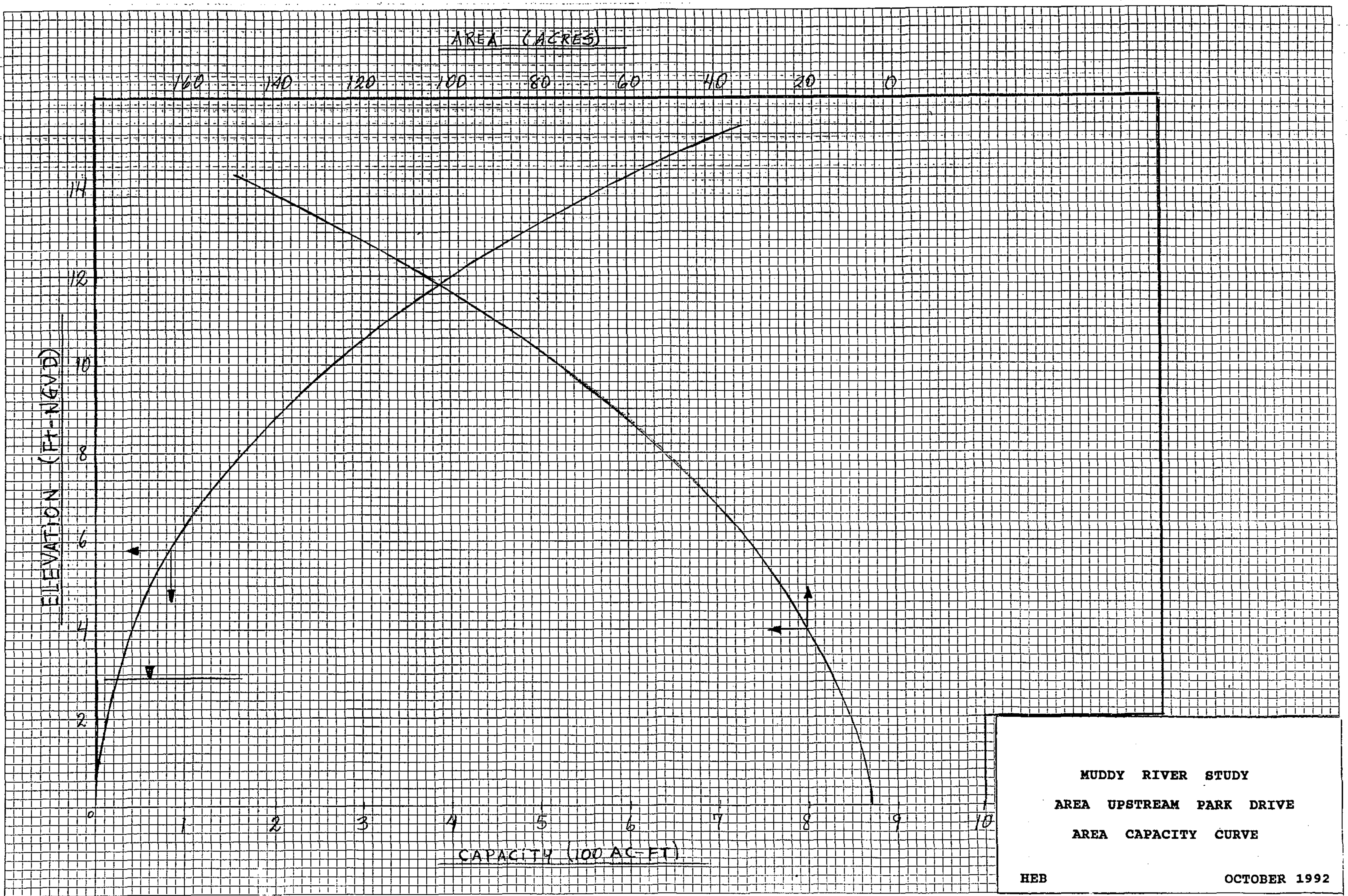

LONGWOOD AVENUE
EMMANUEL COLLEGE
TANNERY BROOK
HUNTINGTON AVENUE.
VILLAGE BROOK
CHESTNUT STREET
DAISY FIELD
SARGENT POND
JAMAICA POND
BOSTON
BROOKLINE
CHARLES RIVER
MIDDLESEX CO
SUFFOLK CO
NORFOLK CO
Chestnut Hill Reservoir
Jamaica Pond
Brookline Res
Hammond Pond
Chandler Pond
BOSTON COLLEGE
BOSTON UNIVERSITY
The Country Club
Putterham Meadows Country Club
Coolidge Corner
Roxbury Crossing
Back Bay
Brighton
MUDDY RIVER RECONNAISSANCE STUDY
BASIN MAP
HEB
NOV 1992

PLATE B-1



MUDDY RIVER STUDY

AREA UPSTREAM PARK DRIVE

AREA CAPACITY CURVE

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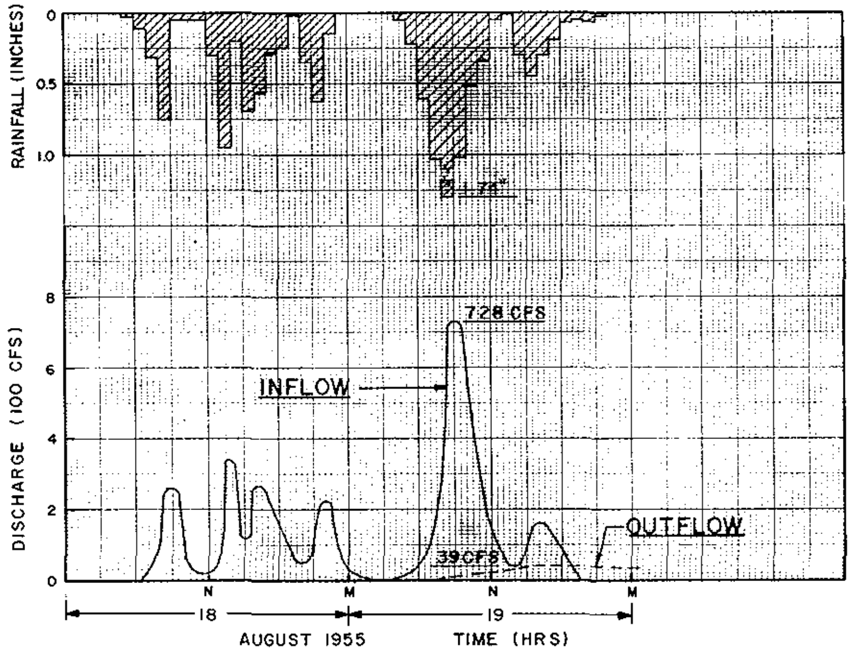
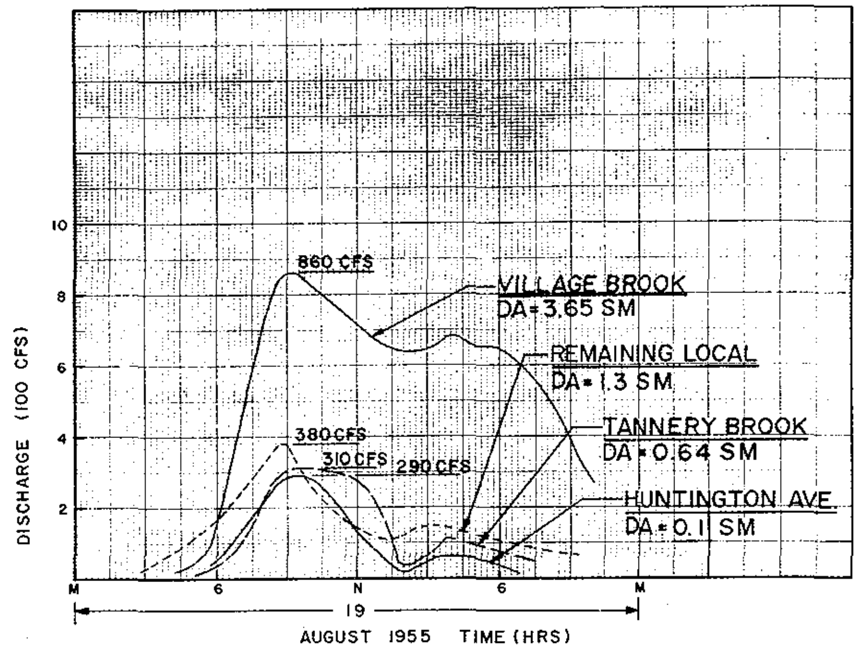
OCTOBER 1992

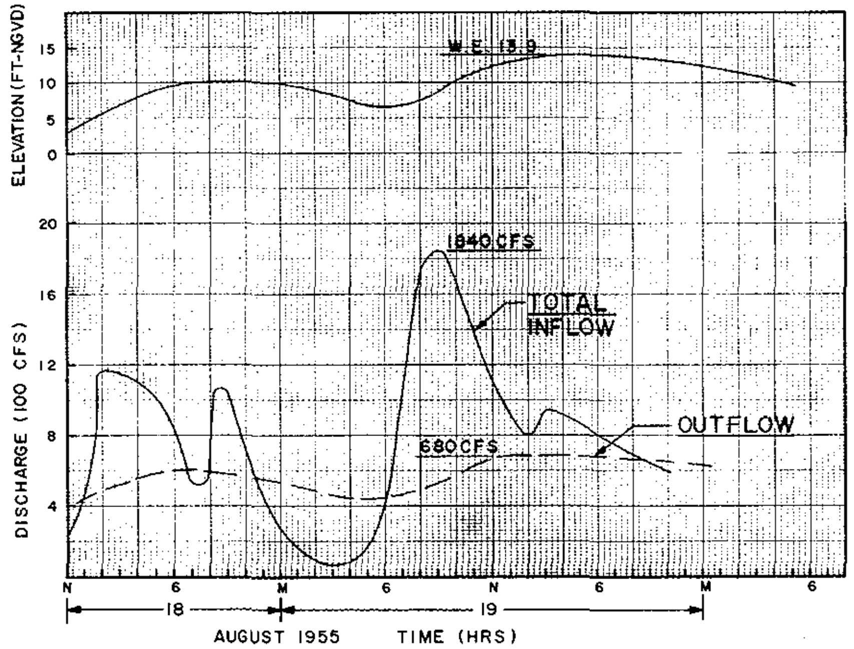
PLATE B-2



JAMAICA POND



INPUT HYDROGRAPHS



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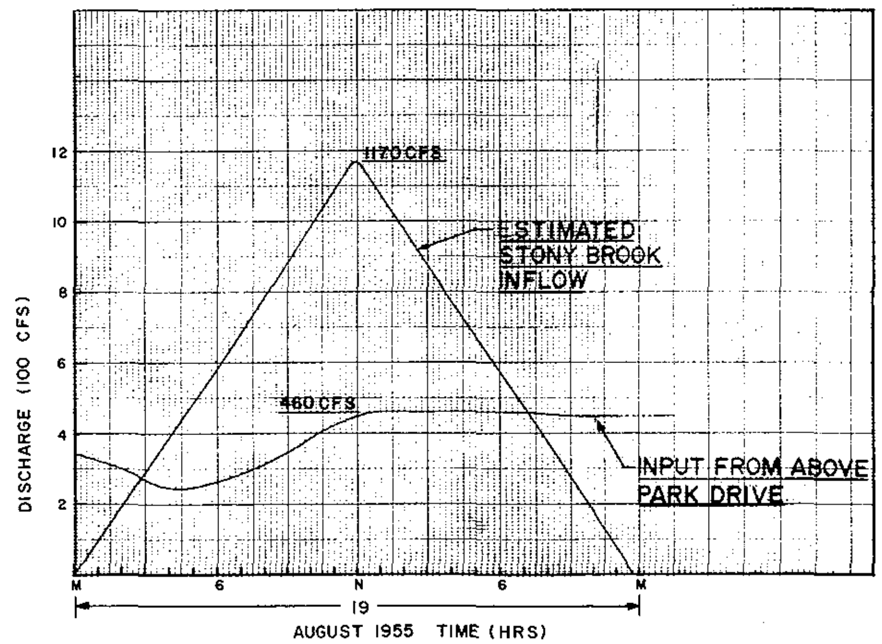


BACK BAY FENS AREA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER STUDY

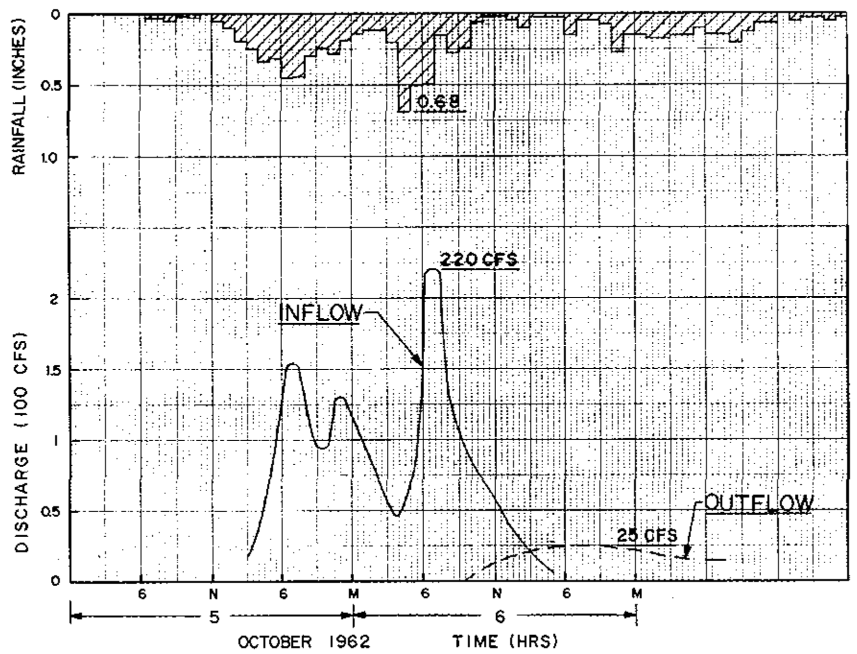
1955 FLOOD ANALYSIS

EXISTING CONDITIONS

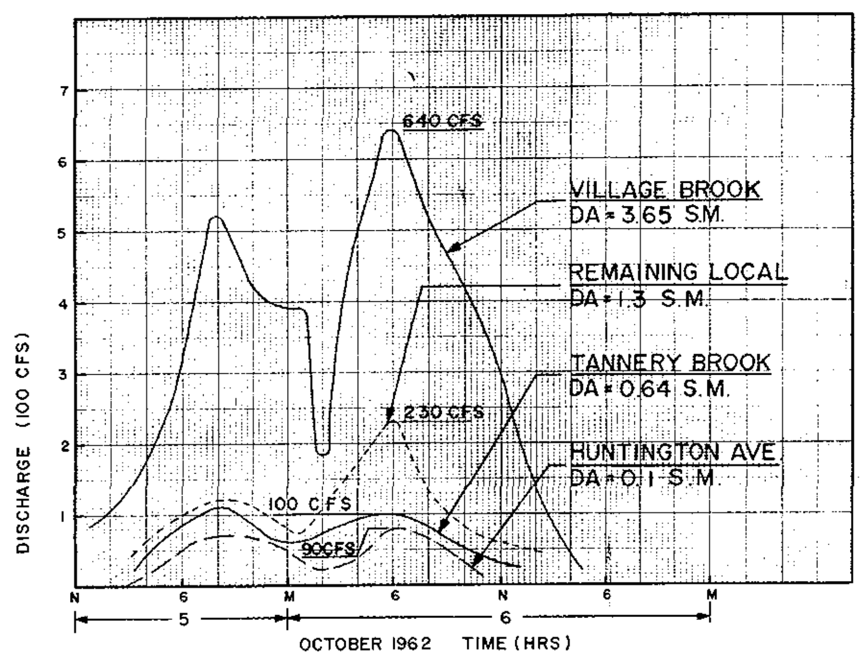
HEB

OCT. 1992

PLATE B-3



JAMAICA POND
DA: 1.1 S.M.



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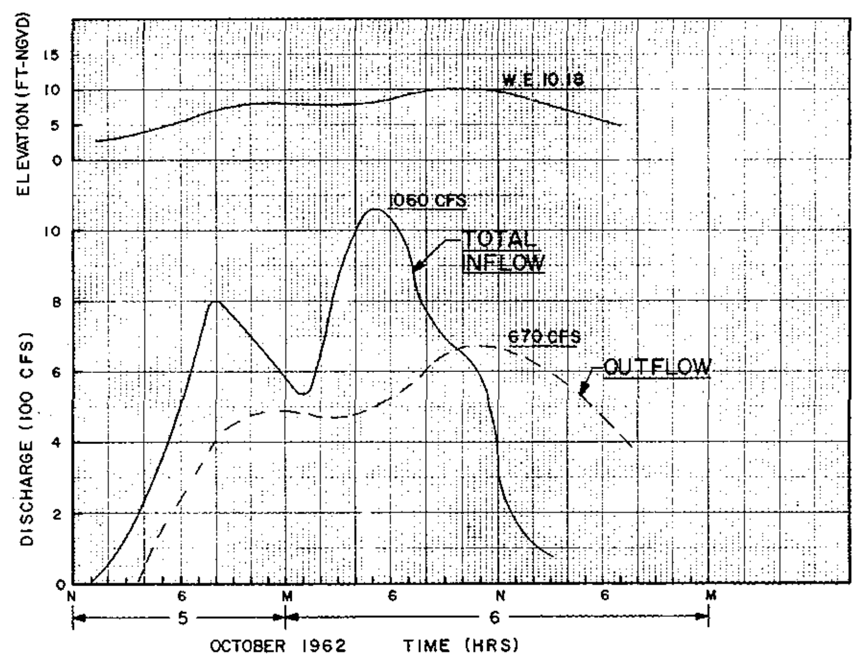

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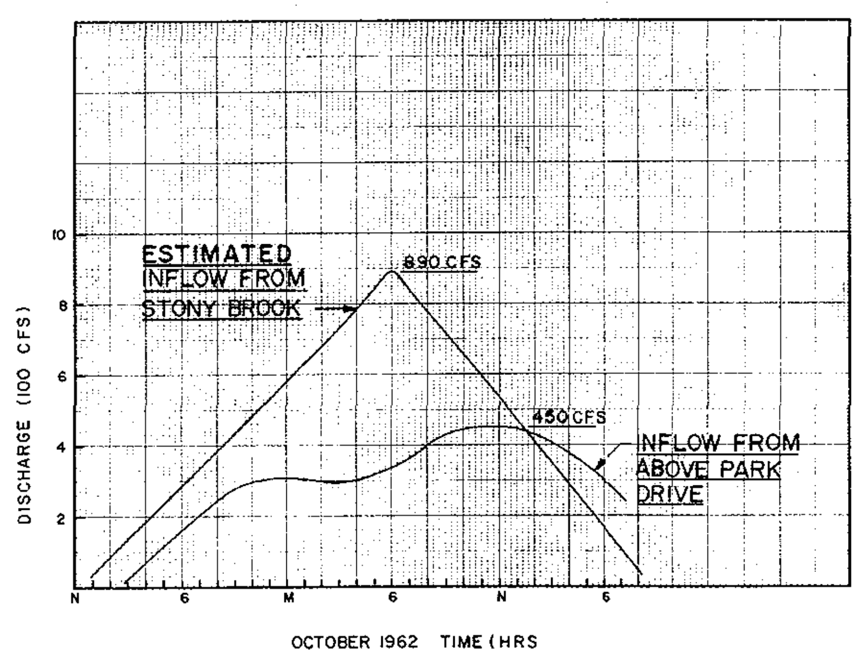


BACK BAY FENS AREA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER STUDY

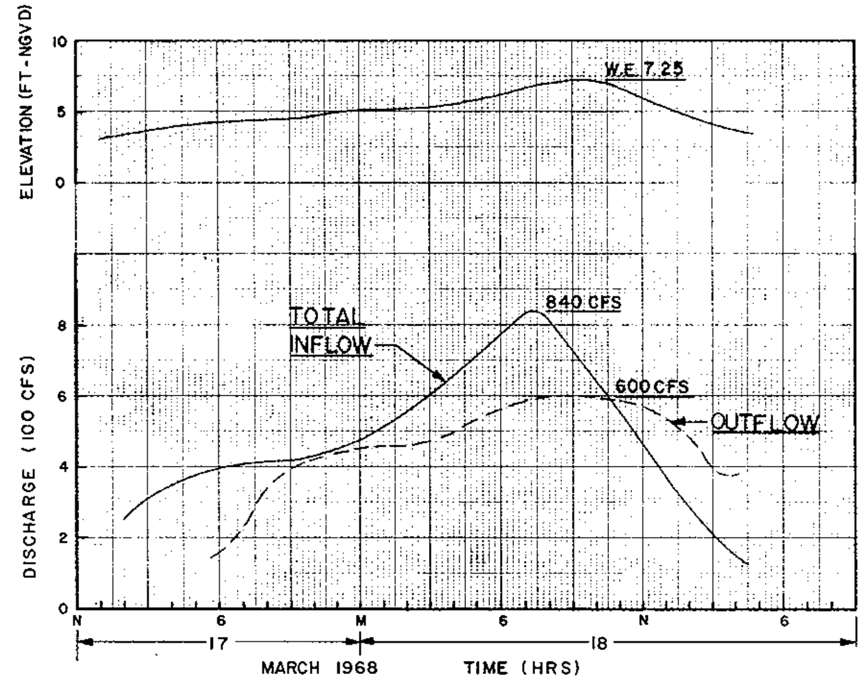
1962 FLOOD ANALYSIS

EXISTING CONDITIONS

HEB

OCT. 1992

PLATE B-4



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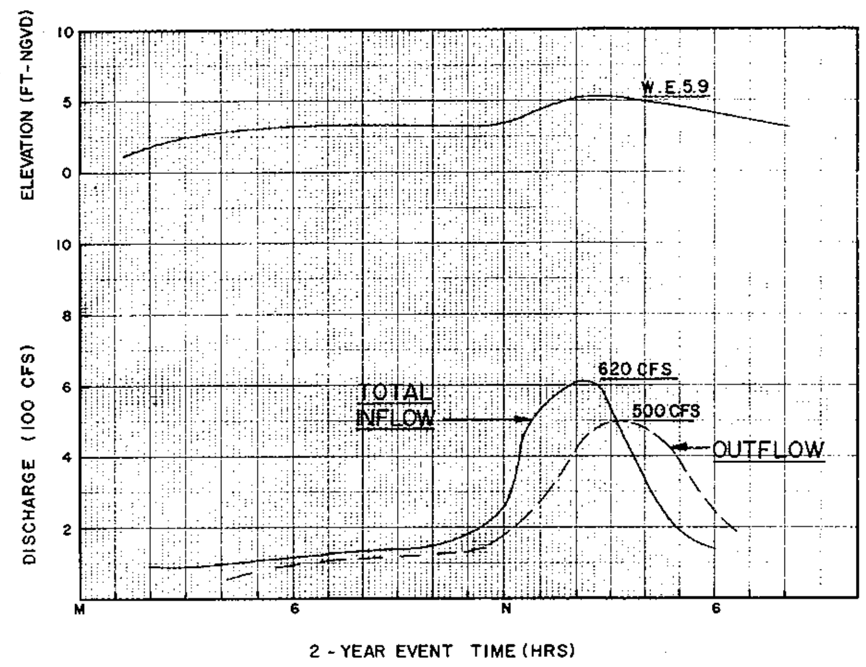

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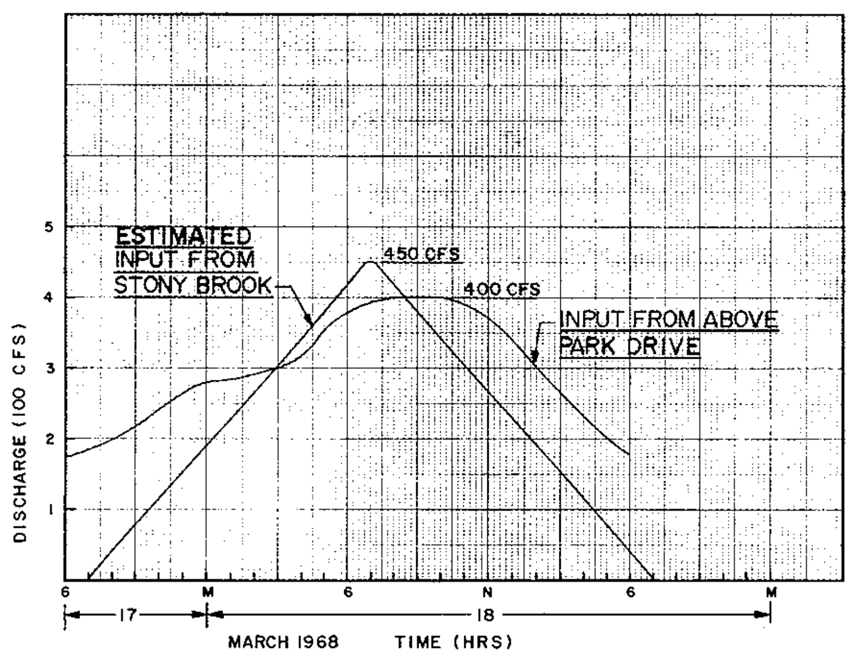
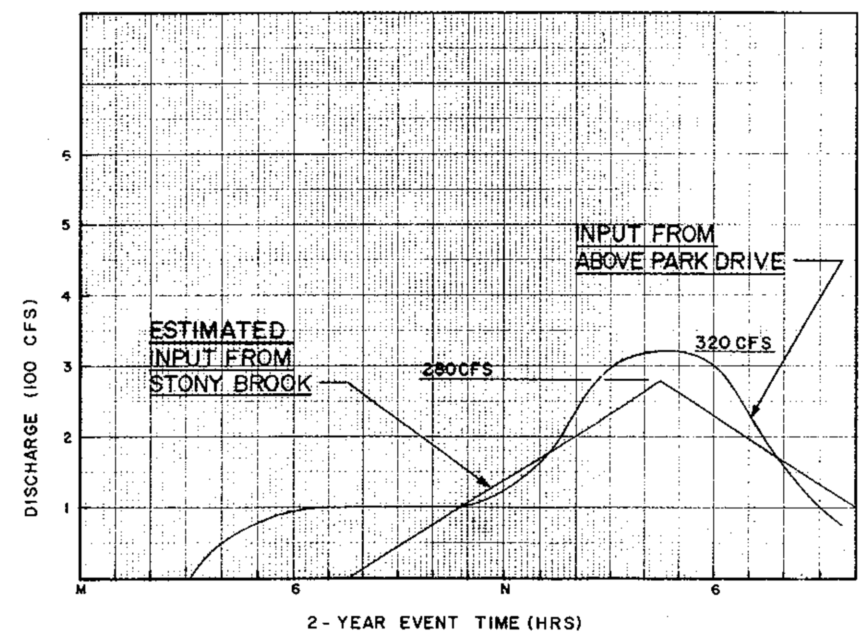


BACK BAY FENS AREA



BACK BAY FENS AREA

DEPARTMENT OF THE ARMY
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CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER STUDY

FLOOD ANALYSIS

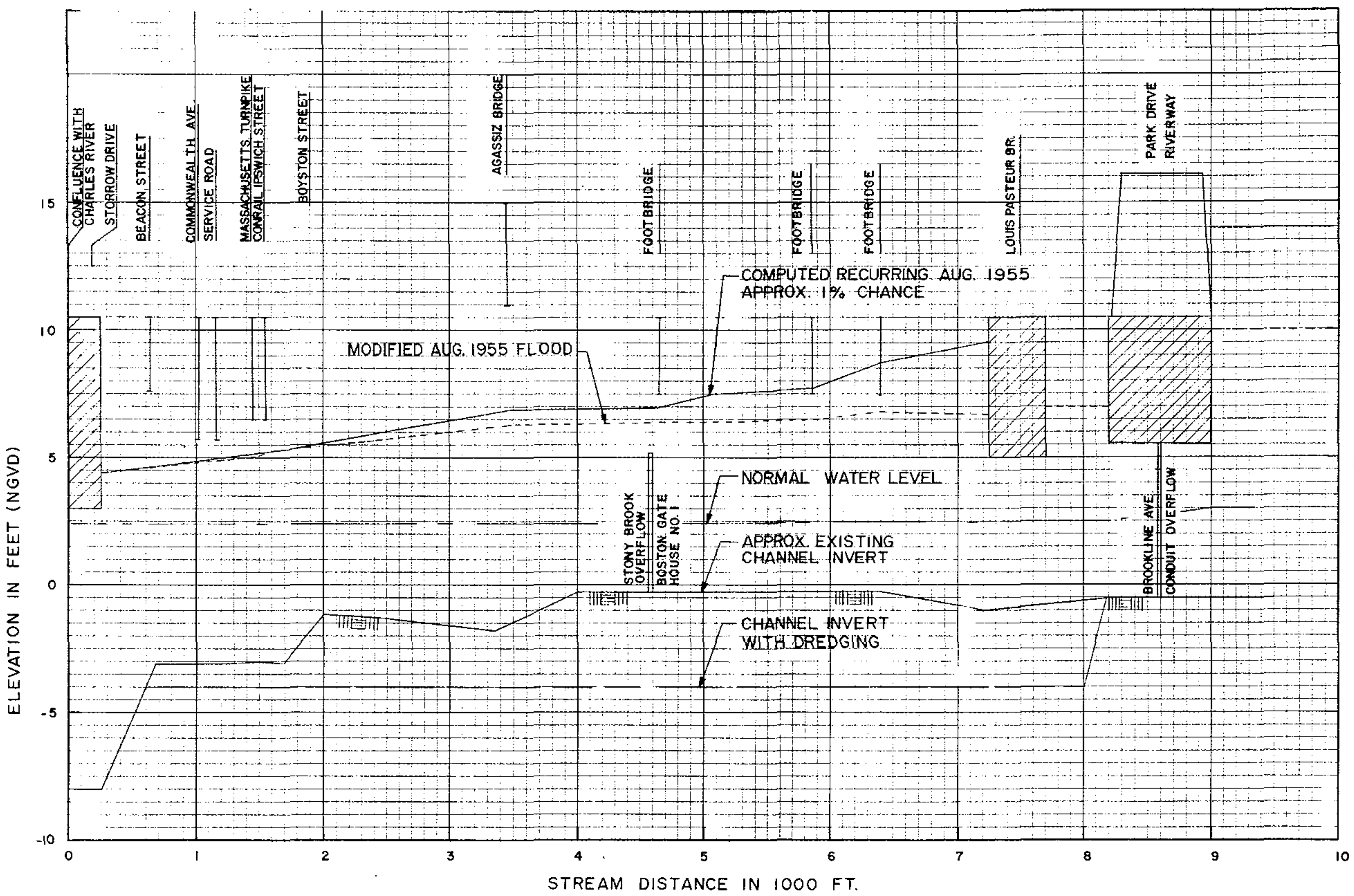
1968 - 2 - YEAR

EXISTING CONDITIONS

HEB

OCT. 1992

PLATE B-5



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CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER BASIN

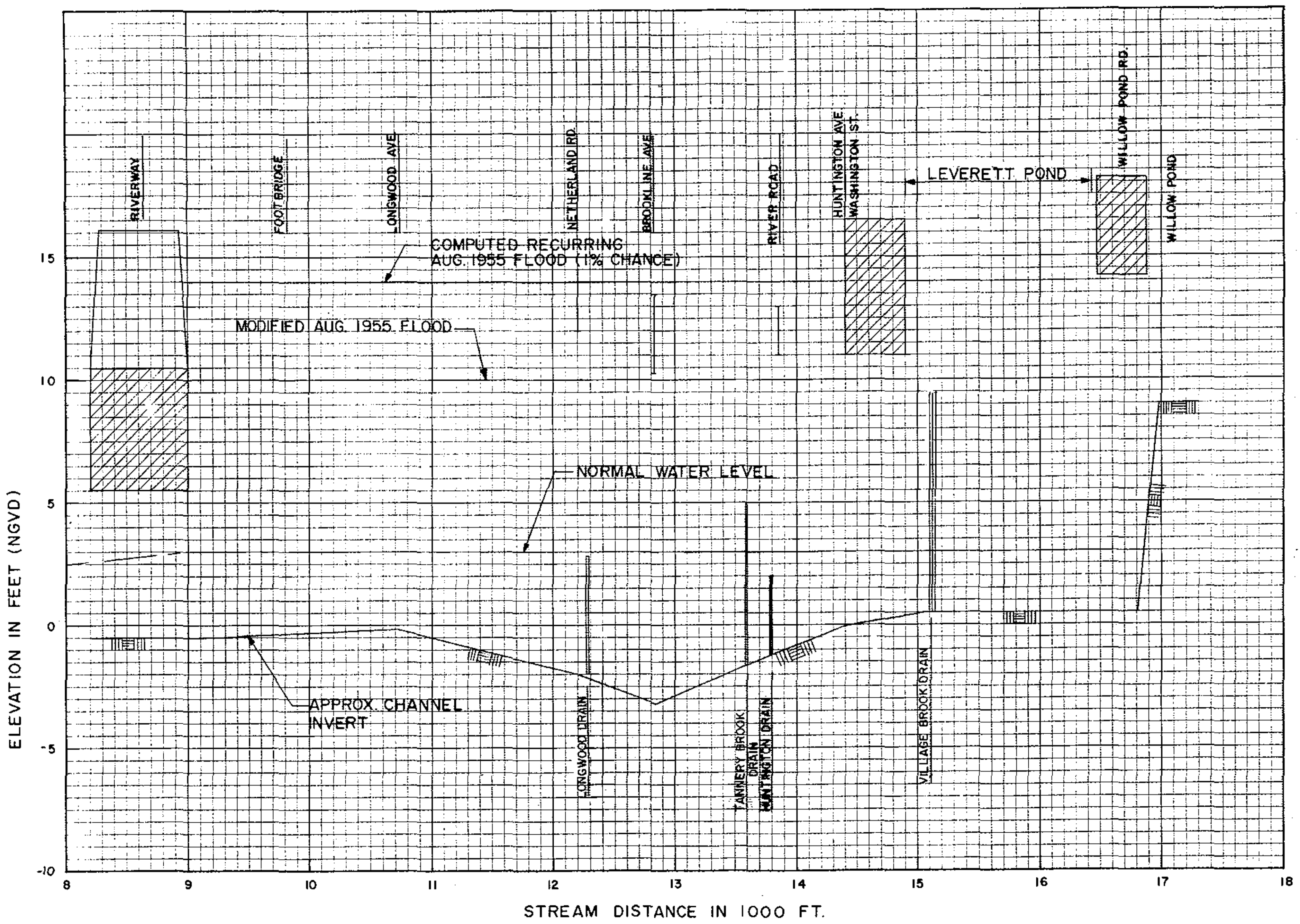
RIVER PROFILE

AUGUST 1955 ANALYSIS

EXISTING AND IMPROVED CONDITIONS NO. 1

HEB OCT. 1992

PLATE B-6



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WALTHAM, MASS.

MUDDY RIVER BASIN

RIVER PROFILE

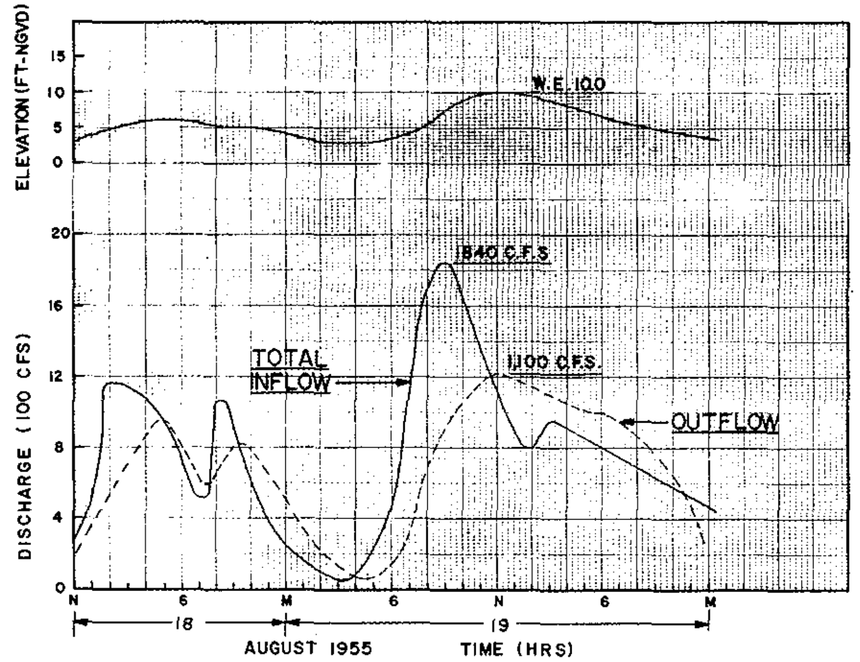
AUGUST 1955 ANALYSIS

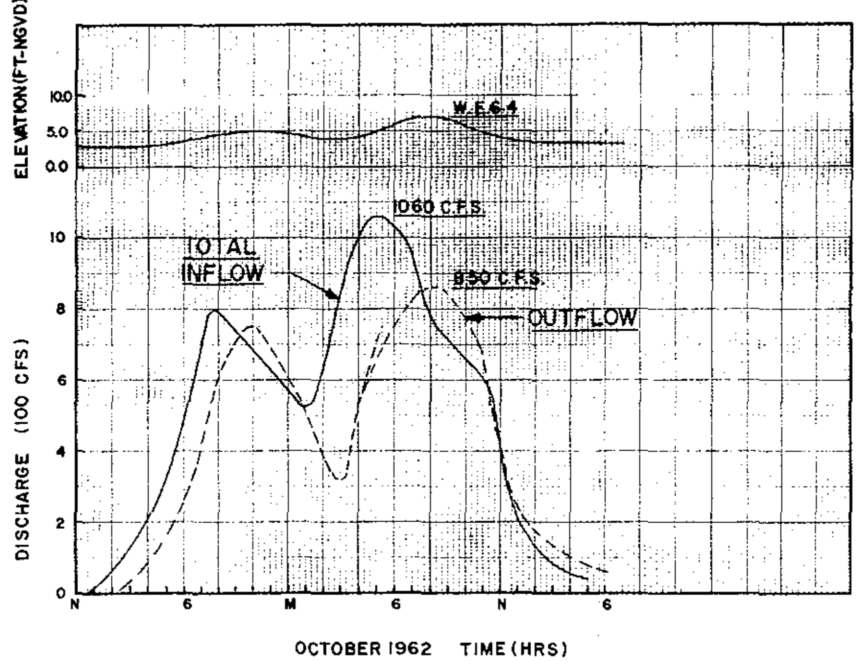
EXISTING AND IMPROVED CONDITIONS NO. 2

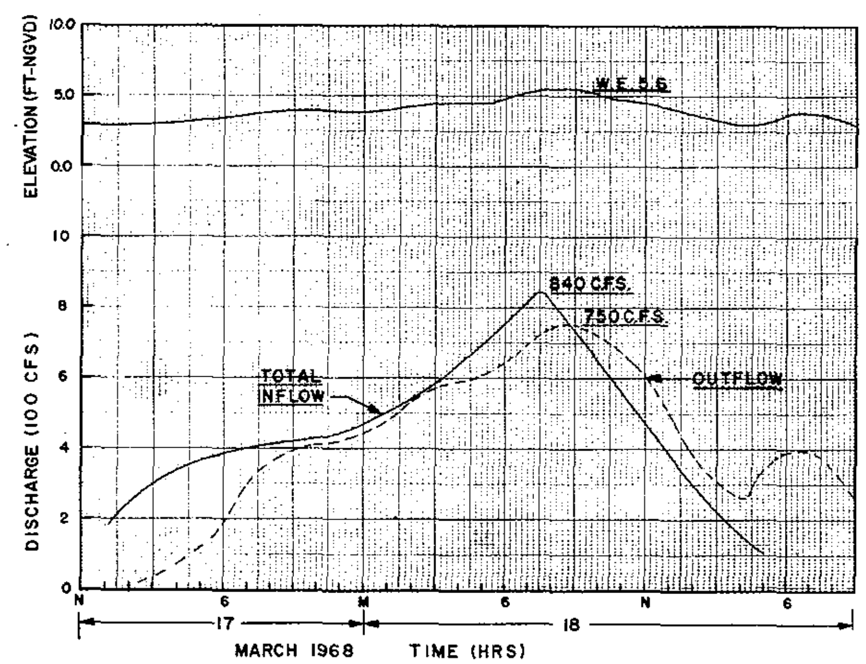
HEB

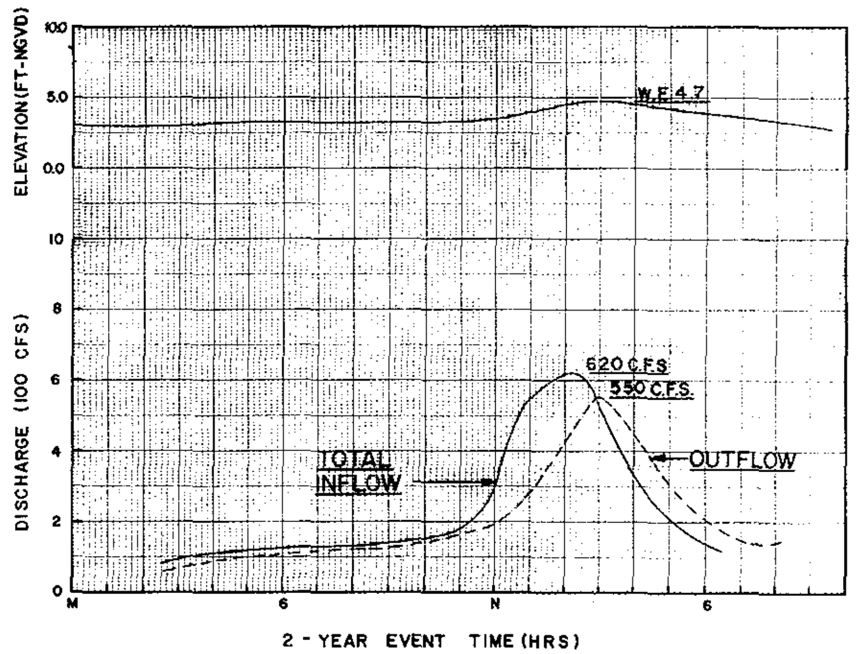
OCT. 1992

PLATE B-7









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WALTHAM, MASS.

MUDDY RIVER STUDY

FLOOD ANALYSIS

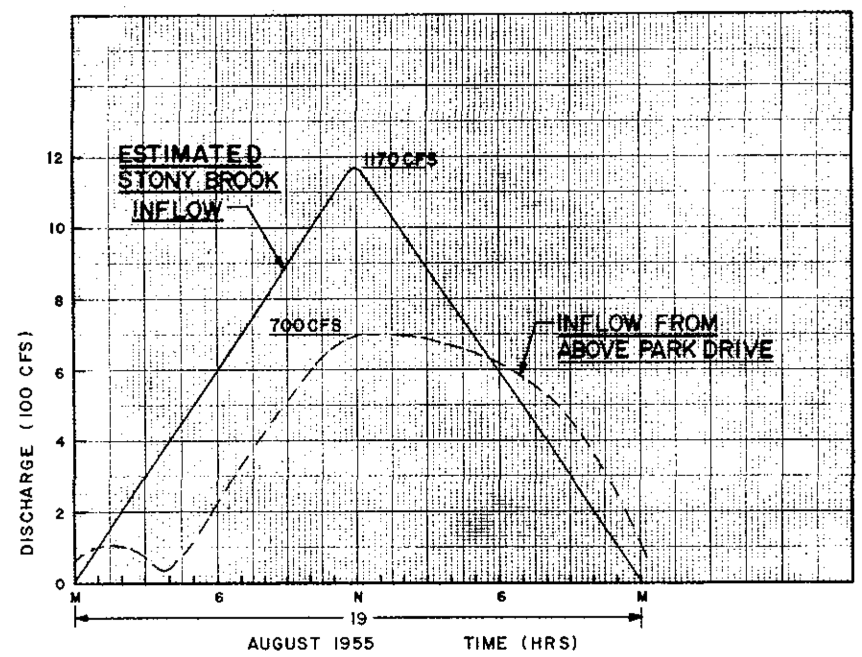
UPSTREAM - PARK DRIVE

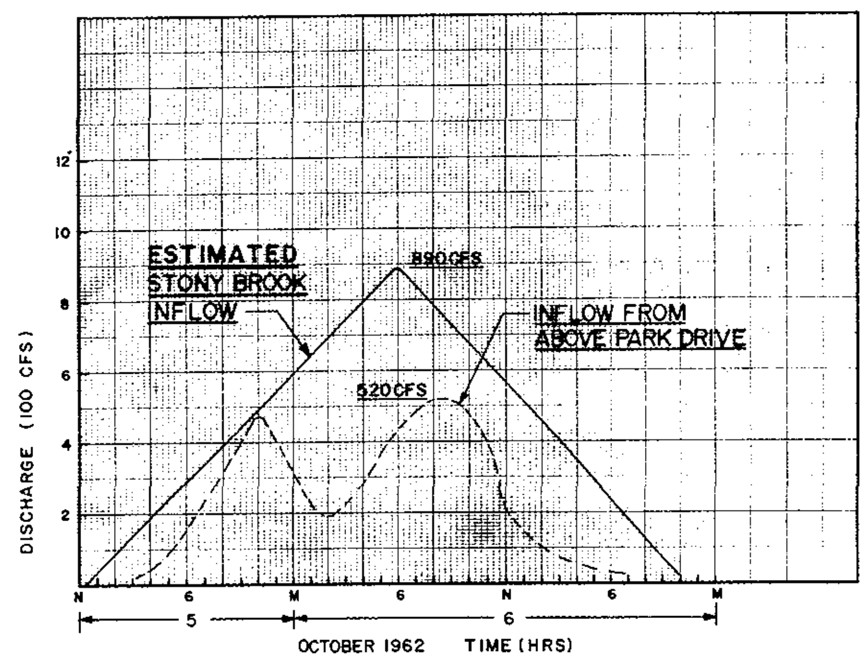
COMPREHENSIVE PLAN

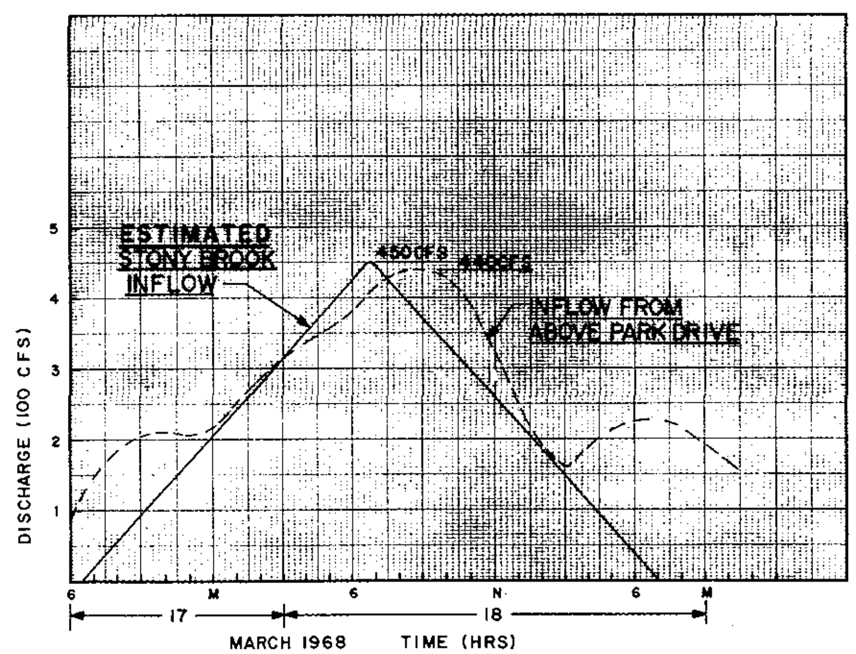
HEB

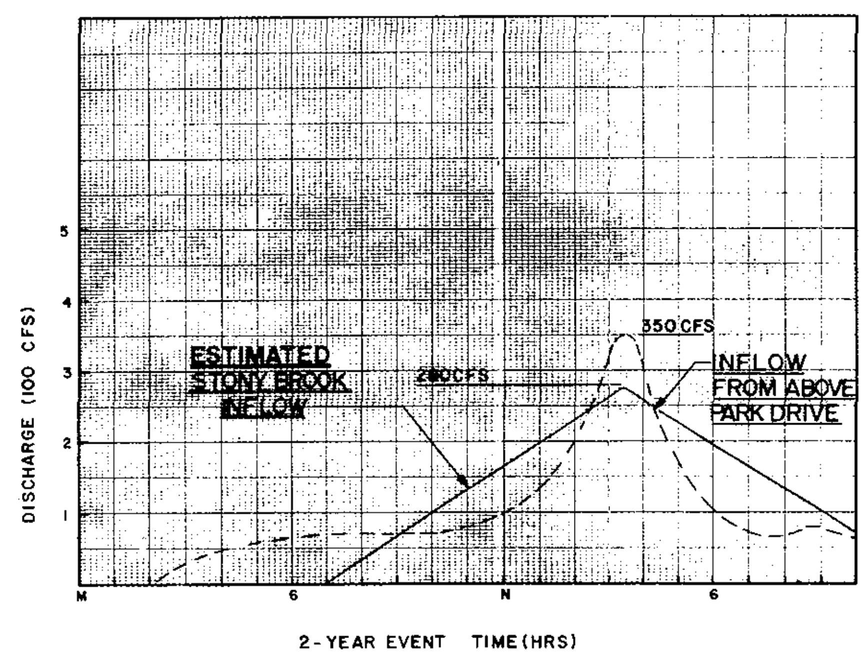
OCT. 1992

PLATE B-8









DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER STUDY

FLOOD ANALYSIS

BACK BAY FENS PARK

COMPREHENSIVE PLAN

HEB OCT. 1992

PLATE B-9

MUDDY RIVER RECONNAISSANCE STUDY
WATER QUALITY EVALUATION

BY
HYDRAULICS & WATER QUALITY BRANCH
WATER CONTROL DIVISION
ENGINEERING DIRECTORATE

APPENDIX C

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS 02254-9149

NOVEMBER 1992

APPENDIX C
MUDDY RIVER RECONNAISSANCE STUDY
WATER QUALITY EVALUATION

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APPENDIX C

MUDDY RIVER RECONNAISSANCE STUDY WATER QUALITY EVALUATION

1. INTRODUCTION

a. General. As part of the Muddy River Reconnaissance Study being prepared by the New England Division Corps of Engineers (NED), this document presents existing water quality conditions within the basin, possible water quality improvement options, and briefly describes water quality impacts of potential flood control actions.

b. Study Authority. Due to Federal, State, and local concerns with water resources of the Muddy River Basin, funds were provided to the Corps of Engineers in the Fiscal Year 1992 Energy and Water Development Appropriation Act to perform this investigation. This study is being conducted under authority contained on a Resolution of the Senate Committee on Public Works, adopted September 12, 1969, which states:

> "That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby requested to review the report on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining the feasibility of providing water resource improvements for flood control, navigation and related purposes in Southeastern New England for those watersheds, streams and estuaries which drain into the Atlantic Ocean and its bays and sounds in the reach of the coastline of Massachusetts, Rhode Island and Connecticut southerly of, and not including, the Merrimack River in Massachusetts, to, and including, the Pawcatuck River in Rhode Island and Connecticut, with due consideration for enhancing the economic growth and quality of the environment."

2. WATERSHED DESCRIPTION

a. General. The Muddy River (D.A.= 7.5 square miles), a minor tributary of the Charles River (D.A.= 309 square miles) is located within the communities of Boston, Brookline and Newton, with the channel forming the boundary between Boston and Brookline for almost its entire length. The river originates from Jamaica Pond (a 68-acre spring-fed "kettle" pond), flowing north through a series of small ponds, interconnected by short stretches of covered and uncovered waterways for a length of approximately 3.5 miles, before entering the Charles River about 3 miles upstream from its mouth. A map of the drainage area is shown in plate C-1, and a more detailed plan view of the river is shown in plate C-2.

The Muddy River watershed is occupied generally by commercial and densely populated residential properties, hospital and college facilities, public park land, and trackage of the Massachusetts Bay Transportation Authority's rapid transit line between Boston and Newton. The waterway is within a series of Boston area parks referred to as the "Emerald Necklace," designed in the 19th century by landscape architect, Frederick Law Olmsted.

b. Topography. Elevations of the Muddy River Basin range from approximately 300 feet NGVD in the western part of the basin in Newton to slightly under 10 feet NGVD at the confluence of the Muddy River with the Charles in Boston. There are small hills scattered throughout the upper basin, with flat lands prevailing in the filled-in Back Bay portion of Boston. Other than the ponds directly connected to the Muddy River, the only major water bodies included in the basin are the Chestnut Hill and Brookline water supply reservoirs. The entire basin is covered by a patchwork of major traffic arteries and smaller side streets.

c. Hydrologic Overview

(1) Muddy River. The Muddy River loses 20 feet in elevation over its approximately 500-foot length between Jamaica and Ward's Ponds (see plate C-3). The 18-inch discharge outlet from Jamaica Pond is reportedly gated, however, the status of gate setting is unknown. During several NED visits, an insignificant amount of flow was seen exiting from the outlet, suggesting that the pipe may also be partially clogged. Most inflow into the 3-acre, 5-foot deep Ward's Pond appears to be comprised of groundwater seepage entering from the direction of Jamaica Pond. The pond's discharge flows north as a small meandering stream to Willow Pond, a tiny one-acre water body. The stream drops approximately 30 feet in this reach over a distance of approximately 1,400 feet. A second inlet enters Willow Pond from an underground spring from the southeast in the direction of Metropolitan District Commission's (MDC) skating rink, off Willow Pond Road. The outlet from Willow Pond is a culvert, which surfaces just upstream from Leverett Pond. The river drops approximately 9 feet in the 400-foot length between the ponds. Leverett Pond is a shallow (approximately 6-foot deep), oblong, 12.8-acre pond surrounded by a grassed park land. A major tributary of the pond is the Village Brook drainage conduit, entering Leverett Pond from the northwest just upstream of the pond's outlet.

From Leverett Pond, the Muddy River flows north under Route 9 and Brookline Avenue, continuing through parkland containing grassed areas, walking trails, and benches, and running parallel to the Riverway and MBTA Green Line until it reaches Park Drive near the Sears building. During normal flow, the river is extremely slow-moving in this area. In the southern portion of this reach, the river is straight, 20 to 50-feet wide, and 1 to 2-feet deep, with dense aquatic vegetation on either bank. In the northern portion of this reach between Netherlands Road and Park Drive, the river broadens from approximately 50 to 150 feet in width.

At Park Drive and Riverway, the river flows through two 6-foot diameter culverts to Brookline Avenue, where it enters a currently inoperable gatehouse. Originally, this structure was put in to divert polluted water directly to the Charles River and away from the Back Bay Fens via the Muddy River Conduit underneath Brookline Avenue. The gates in this structure, previously set up to divert nearly 90 percent of the flow down the 9 by 11 foot Muddy River conduit, were reportedly removed in the late 1940s. Now, the only control is the conduits size and slope characteristics. A portion of the flow now passes through the Muddy River Conduit to the Charles River at Deerfield Street. The remainder continues on toward the Back Bay Fens through a 7 by 9 foot conduit, passing through an overflow structure at Brookline Avenue, and then continuing through two 6-foot diameter culverts finally entering the Fens. Although the flows have never been accurately measured, we estimate that approximately 40 percent of the total flow bypasses the Fens and goes through the Muddy River Conduit.

The Back Bay Fens, approximately 1.5 miles in length, enters the Charles River just above the Harvard Street bridge at the Charlesgate interchange. The Fens is the remainder of the 750-acre Back Bay of the Charles River, which was filled in the mid-nineteenth century. The Muddy River enters the 9.0 mile long, nearly constant level Charles River Basin, approximately 2.2 miles upstream from the new Charles River Dam. There are no U.S. Geological Service flow gages on the Muddy River. Estimates of average daily flow have been developed from data collected at a nearby stream gage and are estimated at 12 cfs. Because of this low flow and as a result of the backwater condition created by the Charles River Basin impoundment, water movement through the Back Bay Fens is extremely sluggish.

(2) Charles River Basin. This basin extends generally eastward from the Watertown Dam, Watertown, at river mile 9.8, through parts of Newton, Cambridge, and Boston to the Charles River Dam, in Boston, at approximate river mile 0.8. This portion of the river was originally a tidal estuary until construction of the old Charles River Dam in 1910, approximately 0.4 mile upstream from the new dam at Leverett Street, which was completed by the Corps of Engineers in 1978. Primary objectives of the original dam were to create a freshwater pool eliminating the extensive mud flats and noxious odors at low tides, to protect low areas in Boston and Cambridge from high tides, and to maintain a fairly constant Basin level to stabilize the groundwater table in adjacent areas. In addition to the old dam, marginal sewage conduits were constructed along both the Boston and Cambridge banks of the river to reduce pollution in the Basin, by carrying sewage directly to the harbor.

The Charles River Basin watershed is 41.3 square miles, which is small compared to the 265.3 square miles of the upper Charles River. However, the lower watershed is the contributor of 90 percent of peak flood flows within the Charles River Basin. This is primarily the consequence of the high percentage of impervious ground cover, which is characteristic of the urban watershed. The terrain is mostly flat to gently rolling, with elevations ranging from less than 10 to over 200 feet NGVD.

The normal basin elevation is 2.4 feet NGVD. The Basin has a maximum width of about 2,000 feet, which gradually decreases to less than 400 feet at the Boston University Bridge. The depth of water varies from approximately 3 feet deep just downstream from the Watertown Dam, to approximately 30 feet near the new Charles River Dam. The new dam was constructed in 1978 to provide more dependable flood protection of low lying urban areas, adjacent to the basin, during major coincident freshwater and/or tidal events. Major flood control components of the new dam are six flood control pumps, which have a total capacity of 8,400 cfs against a 9-foot static head. These pumps, along with two sluiceways, discharge capacity provided by the boat lock system (consist- ing of one large and two small boat locks, and their associated filling and emptying systems), enable the water level to remain nearly constant within the basin. This, in turn, creates a nearly constant water surface for the Back Bay Fens during average and low flow conditions.

3. POLLUTANT SOURCES

a. General. Pollutant sources were first identified by a review of historical reports (see References, Section 7). According to field investigations in Metcalf and Eddy's (M&E) "Muddy River Water Quality Improvement Plan," dated September 1990, almost the entire Muddy River watershed is served by a separate sewer system. The only exceptions are two combined sewer overflows, occurring in the Back Bay Fens from the Stony Brook and Old Stony Brook Conduits. According to M&E, there are 111 pipes discharging into this river.

Ninety-four pipes discharge from storm drain systems, seven are subsurface drain outlets, two are overflows from combined sewer systems, three are from water main blowoffs, three are interconnections between the Muddy River water bodies, one is an outlet from Sargent Pond in Brookline, and one is an abandoned pipe (the former Village Brook Drain in Brookline). Plate C-3 is a figure taken from M&E's report, showing location of the outlet pipes which enter the Muddy River. Each pipe has been identified with a number defined in M&E's report. However, for information purposes, the largest contributors to Muddy River's flow have been labelled on plate C-3. Table 1 lists significant past and potential sources which are further described in the following sections.

b. Storm Drainage System. Muddy River's storm drainage systems are extremely complex, not only due to the highly urbanized development in each area, but also the systems' age. Most were built in earlier years when undocumented construction was allowed. The manmade system of the major underground drains approximates the natural drainage pattern of surface streams that existed before the drains were constructed. Pollutant problems associated with the storm drainage discharges from dense urban development include nutrient and pesticide loads from lawn and garden maintenance, street litter, organic loads and bacteria from street runoff of animal wastes and vegetative matter, metals and petroleum products from automobiles, street runoff of deposited air pollutants, and inorganic sediment and suspended solids loads from overland runoff.

TABLE 1
SUMMARY OF FORMER AND POTENTIAL
PRESENT POLLUTANT SOURCES

Storm Drainage System	Catchment Area (Acres)
Village Brook	1,965
Tannery Brook	354
Chestnut Street	179
Longwood Avenue	191
Sargent Pond	300
Huntington Avenue	70
Daisy Field	71
Emmanuel College	70

Combined Sewers	Source
Stony Brook	DA = 13.9 sq. mi.
- Stony Brook Conduit	Hyde Park, Roslindale, Jamaica Plain, and Roxbury
- Old Stony Brook Conduit	Roxbury
Brookline Main Sewer	Brookline
MWRA Brighton Branch Sewer	Brighton, Brookline

Other	
Francis Street Siphon	Roxbury, Jamaica Plain
Oil Spill near Willow Pond	Unknown
Refrigerant Leak near Willow Pond	MDC Skating Rink

Only 20 storm drain outlets have catchment areas greater than 5 acres in size. The eight largest drainage systems, with areas taken from M&E's report, are Village Brook (1,965 acres), Tannery Brook (354 acres), Chestnut Street (179 acres), Longwood Avenue (191 acres), Sargent Pond (300 acres), Huntington Avenue (70 acres), Daisy Field (71 acres), and Emmanuel College (70 acres). These areas account for 80 percent of the total drainage area tributary to the Muddy River. The Sargent Pond area is the only one which does not have a complex network of drains, since a majority of the area includes Sargent Pond itself and several open drainage ditches. Outflow from Sargent Pond enters the northern shore of Jamaica Pond by way of a brook.

Sources of potential contamination relating to use or lack of best management practices within the Muddy River drainage basin were investigated by M&E in the previously mentioned report. Representatives of various agencies responsible for source control activities were contacted and interviewed about their practices of street sweeping, storm drain and sewer maintenance, catch basin cleaning, road salting, fertilizer application on park land, trash collection and erosion control. A summary of the measures and their frequencies are presented in table 2, as extracted from the M&E report.

In addition to interviews and review of drainage plans, M&E carried out physical inspections of 50 representative manholes in the Muddy River drainage system to identify outlets that may discharge sewage, oil, or other wastes to the river. During these inspections, they found three of the larger tributary areas, namely, Village Brook, Tannery Brook, and Longwood Avenue systems, appear to contain sewage during dry weather conditions. A fourth system, serving the Daisy Field drainage area, was observed having a wet weather discharge appearing to contain sewage. Storm drainage areas suspected of having sewage cross connections were identified by M&E, and a figure depicting these areas, extracted from their report, is shown in plate C-4. This information was corroborated when the Massachusetts Water Resources Authority (MWRA) made a cursory visual investigation of the river in November 1988 to identify dry weather flow in the storm drains. Two areas identified as problems were a drain discharging during dry weather from Huntington Avenue, and the Tannery Brook drain, discharging a milky white flow with a strong sewage smell.

More recent action by both Brookline and Boston in investigating and removing sewage cross connections may have rendered some of M&E's identified pollutant inflows out-of- date. For instance, the town of Brookline recently completed the "Tannery Brook Storm Drain Investigation," using its con- sultant, Camp Dresser & McKee. This report identified 22 positive and 32 possible sewage connections. The town has since moved to eliminate some, if not all, of these connections. The city of Boston has also investigated areas with potential cross connections (most notably, the Daisy Field drain), identified in the M&E report. Progress has also been made in eliminating these sources.

Given the difficulty and costliness in correctly identifying and addressing all cross connections, it is readily apparent that elimination of all sewage connections will be a long

TABLE 2
SUMMARY OF BEST MANAGEMENT PRACTICES

AGENCY CONTACTED	RESPONSIBILITIES AND FREQUENCIES
Brookline Department of Public Works	Street sweeping (3 times/month), catch basin cleaning (2 times/year), sewer and storm drain maintenance (as needed), and erosion control in Brookline.
Brookline Department of Parks	Trash collection, landscaping and fertilizer application (once a year) in parks.
Boston Water and Sewer Commission	Catch basin cleaning (one to two times per year), and sewer and storm drain maintenance (as needed).
Metropolitan District Commission	Street sweeping (weekly), catch basin cleaning (annually), and road maintenance of Park ways surrounding the Muddy River.
Boston Parks and Recreation Commission	Trash collection, landscaping and fertilizer application (once a year) in parks.
Boston Department of Public Works	Street sweeping (weekly), trash collection, road maintenance, and erosion control in Boston.

Source: "Muddy River Water Quality Improvement Plan," dated 1990 by M&E.

term project, which can only be completed after intense effort. Based on the results of M&E's study, and subsequent water quality data collected by NED during the summer of 1992 as part of this study, there are still significant cross con- nections existing in the systems at this time. We highly recommend that a program of thorough investigation and action be developed and continued until all cross connections contributing to Muddy River have been positively identified and removed from the storm drain systems of Boston and Brookline. A monitoring program should be established in each drain and river area until this complete cleanup program is reached.

c. Subsurface Drains. Subsurface drains are used to drain groundwater from under walkways and athletic fields in the parks. They also drain under roads to prevent damage from erosion and frost heaving. Drainage from these systems is comprised mostly of groundwater, which may contain nutrients originating from fertilizers applied to the park land; the pollutant contribution is fairly minor.

d. Combined Sewers. In addition to the Muddy River, another major local tributary to the Charles Basin is Stony Brook. From its source at Turtle Pond in the Stony Brook Reservation, the brook flows underground for most of its length in the Stony Brook Conduit. This brook, draining 13.9 square miles, was originally an open channel for stormwater alone. It flows through Hyde Park, Roslindale, Jamaica Plain, and Roxbury before ending at Gatehouse No. 1 on the Fens. Upper reaches of the tributary are served by separate sewers. Below the Arnold Arboretum in Jamaica Plain, a combined sewer system serves the drainage area. There are seven overflow connections from combined sewers to the conduit, and past sampling has indicated that dry weather sewage flow is leaking into the conduit from either malfunctioning CSO regulators or illegal sewer connections to the conduit.

At Boston Gatehouse No. 1 on the Fens, dry and wet weather flows from the Stony Brook Conduit are supposed to be diverted to a 12-foot "foul flow" channel, flowing to the Charles River at MDC's Fens Gatehouse near the Charlesgate interchange. During large storms, two of the four 8 by 13-foot sluice gates of Gatehouse No. 1 may be opened manually, allowing combined sewage to flow into the Fens (the frequency of these gate openings is approximately 2 to 3 times a month). The gate opening allows large amounts of sludge, deposited in the bottom of Stony Brook Conduit, to flow into the Fens. In addition, overflows may still occur into the Fens without opening the gates, since the flow can overtop the closed sluice gates during major storm events.

In addition to Stony Brook Conduit, Old Stony Brook Conduit, originating in Roxbury, carries sanitary flow during dry weather from malfunctioning CSO regulators and combined sewage flows during wet weather to Boston Gatehouse No. 2, adjacent to Gatehouse No. 1. Old Stony Brook Conduit enters the Gatehouse as two 10 by 10-foot rectangular brick sewers. Dry weather flows are generally diverted to the Boston Main Drainage Relief Sewer at the intersection of Forsyth and Ruggles Street. Excessive wet weather flows, bypassing this diversion, are generally diverted to a 7-foot foul flow channel, which parallels the 12-foot foul flow channel and empties into the Charles River at the MDC Fens Gatehouse.

However, excess flows sometime discharge into the Fens over the top of the permanently closed sluice gates in Gatehouse No. 2.

The Muddy River subarea upstream from the Fens is served by the Brookline Main Sewer and the MWRA Brighton Branch Sewer. The Brighton Branch Sewer serves approximately 2,100 acres in central Brookline and 350 acres in Brighton. It traverses Brookline in a north to south direction, finally ending up at the MWRA's Nut Island Treatment Plant. The Brookline Main Sewer, serving approximately 715 acres in the northeast part of Brookline, generally follows the Muddy River from Jamaica Road to its connection to the MWRA Charles River Valley Sewer at the intersection of St. Mary's Street and Commonwealth Avenue. There is a combined sewer overflow at this point, discharging to the Charles River Basin during wet weather events. Although the town of Brookline has separated large areas previously served by combined sewers, there are some remaining, which contribute combined sewage to the Brookline Main Sewer during wet weather. At one time, there were two combined sewer overflows discharging sewage to the Muddy River during wet weather. These overflows have been reportedly sealed up with concrete masonry, and eliminated during the late 1980s. The one on Brook Street used to discharge to the Tannery Brook Drain and the other on Kent Square, flowed to the Longwood Avenue Drain. The system's complexity at these former overflows, the recent high coliform measurements near the drain outlets in the Muddy River, and the importance of their impact on overall Muddy River water quality may require further evaluation to assure that all overflow connections in these areas are eliminated.

e. **Other Sources**. In addition to the previously discussed cross connected drain lines, another potential source of sanitary wastes to the Muddy River is the sanitary sewer, crossing the Muddy River from the Francis Street area in Boston to the Brookline Main Sewer in Brookline. The 16-inch sewer, commonly referred to as the "Francis Street siphon," has reportedly in the past surcharged two manholes in the park, and as a result, large granite blocks were placed on top of the manhole covers in an attempt to limit discharges. Recent completion of a sewer separation project on Huntington Avenue in Boston may reduce overflows from the siphon since the project has reduced storm flows into the Brookline Main Sewer, which in turn will reduce the backwater effect on the Francis Street siphon.

Numerous manholes inspected by M&E showed evidence of oil, although no instance of oil discharge at the outlet pipe location was found. Some could be related to small oil discharges from individuals' auto maintenance on city streets. However, there were several instances of major accidental oil spills occurring in previous years as a result of human error and negligence. Presently, there is an oil boom located on Willow Pond to collect surface oil. The oil sheen is readily apparent in this area. The causes of oil spills are unknown, possibly relating to surface spills or from underground leaking tanks. Investigation is ongoing by State and local officials.

In addition, an MDC ice skating rink is suspected of indirectly leaking an ammonia brine solution, used as a refrigerant, to the groundwater which in turn empties into a spring fed pond, finally discharging to Willow Pond. According to the 1990 M&E report, the MDC is under a State mandate to remove the ammonia brine refrigeration system and replace it with a freon-glycol system. There is also a possibility of removing the skating rink as part of the Massachusetts Department of Environmental Management's (DEM) Emerald Necklace Master Plan. In either case, this would result in elimination of the nutrient loading coming from this source.

4. EXISTING WATER QUALITY

a. <u>General</u>. Water quality in the Charles River Basin area has been a continuous problem since the earliest construction of a dam in 1821, across the southerly Back Bay portion of the Charles River estuary. The dam was constructed to provide water power to mill sites on the south side of the Charles estuary, which in most cases were never developed. Additional construction of a Boston and Worcester Railroad, criss-crossing the impounded bay in 1835, further divided the basin, rendering it useless for water power for the mills. Stagnant pools of trapped sewage from public sewers, and polluted tributaries in the impoundment also resulted. Public outcry necessitated the filling of these pools for health reasons. The pools were eventually filled during the period 1859 to 1880, and the general location of the present riverbanks developed as a result of this filling.

What remained of the Back Bay portion of the Charles River was a small basin where the Fens now exists, which received sewage from Roxbury and some of Brookline and Brighton from what was essentially an open sewer, the Muddy River. Frederick Law Olmsted, assigned the task of designing a system to clean up this area, planned to reestablish the Fens as a saltwater environment. The area would be flushed through natural tidal action of Boston Harbor, while pollutants, which were carried in the Muddy River tributary, would be diverted away from the Fens at the Brookline Avenue Gatehouse. In 1883, the Muddy River conduit, constructed along Brookline Avenue, carried heavily polluted Muddy River waters away from the Fens and into the Charles River. The natural flushing and cleansing of the Fens by tidal action, which Olmsted had envisioned, was eliminated when the Charles River Dam was constructed (near the present Museum of Science) in 1910. In 1978, the Corps of Engineers completed a new Charles River Dam downstream from the old one. The new dam did not substantially change the normal basin level, but it allowed better maintenance during high runoff events.

b. <u>Water Quality Classification</u>. Waters in the Muddy River Basin, recently upgraded from Class C in July 1990, are currently classified as Class B according to the Massachusetts Division of Water Pollution Control. This classification is the goal for the waterbody and does not indicate that the waters presently meet this standard. The Charles River, where the Muddy River discharges, is also classified Class B. These waters are considered acceptable for bathing and other recreational purposes; protection and propagation of fish, other aquatic life and wildlife; and after adequate treatment, for use as water supplies. In addition, the Muddy River has been classified as a warm water fishery. Massachusetts class B standards require a minimum dissolved oxygen (DO) concentration of 5.0 mg/l for warm water fisheries, pH in the range of 6.5 to 8.0 standard units or as naturally occurring, fecal coliform not to exceed 200 colonies/100 ml, and color, turbidity, and suspended solids in concentrations that would not exceed recommended limits of the most sensitive receiving water use. Also, waters shall be free of floating oils, grease, and petrochemicals, and pollutants that form objectionable deposits or nuisances. The complete technical requirements for Massachusetts water quality classifications are given in table 3.

c. Water Quality Survey by Others. Several water quality surveys have been conducted within the last 20 years to determine the status of water quality conditions within the Muddy River Basin. Most collected for various State agencies are based on the collection of grab samples within the river. These provide only a snapshot of water quality conditions in the river at the time of sampling. In addition, a Boston University graduate student, Ms. Claire Humphrey, completed a fairly comprehensive water quality analysis of the Muddy River in her Masters Thesis in 1991. Reference was made to her thesis in preparing this report, and verifying measured trends in other water quality surveys. Table 4 lists water quality surveys conducted on the river for various State agencies over the past 20 years.

The most comprehensive data collected from surveys listed in table 4 was developed by the Massachusetts Division of Water Pollution Control (DWPC) in 1974 and 1986. However, since so many changes have taken place in the basin, the 1974 study is nearly outdated. These changes include combined sewer separation programs in Boston and Brookline during the 1980s, recent implementation of regular sewer maintenance, improved catch basin and street cleaning procedures, and completion of the new Charles River Dam in 1978 in Boston.

Construction of the new Charles River Dam significantly reduced salt water intrusion into the Charles River Basin. It also provided more stable basin water levels during normal and flood events than existed since 1910 under the old dam. The present flood control capability of the new dam allows the Charles Basin to remain at nearly a constant level at all times. This has also reduced stage variations and normal flushing in the Fens. However, steeper hydraulic gradients, higher velocities, and less sedimentation probably occur during high flows on the Muddy River with the present more consistent basin level.

Since 1974, regular sewer maintenance, combined sewer separation projects, and enhanced catch basin and street cleaning procedures have improved the water quality in the Muddy River. As a result, additional emphasis has been placed on data collected during the later MA DWPC survey, even though improvements have been made by cross connection removal projects since the 1986 survey. Following is a summary of results presented in the 1986 report, with comparisons made to 1980 and 1988 surveys. Plate C-5 shows the sampling locations and tables 5 through 10 summarize the 1986 survey data.

Dissolved oxygen (DO) levels (table 5) were generally below the water quality standard of 5.0 mg/l in the lower Muddy River and Back Bay Fens. DO levels actually began decreasing to as low as 2.6 mg/l as 5-day BOD levels (table 6) increased above 2.0 mg/l below

TABLE 3
WATER QUALITY CLASSIFICATION CRITERIA
MASSACHUSETTS CLASS B
MUDDY RIVER

Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife, and for primary and secondary contact recreation.

Parameter	Criteria
Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
Temperature	Shall not exceed 83 °F (28.3 °C) in warm water fisheries or 68 °F (20 °C) in cold water fisheries, nor shall the rise resulting from artificial origin exceed 4 °F (2.2 °C).
PH	Shall be in the range of 6.5 to 8.0 standard units and not more than 0.2 unit outside of the naturally occurring range.
Fecal Coliform	Shall not exceed a log mean for a Bacteria set of samples of 200 per 100 ml, nor shall more than 10 percent of the total samples exceed 400 per 100 ml during any monthly sampling period.
Aesthetics	All waters shall be free from pollutants in concentrations or combinations that: a. Settle to form objectionable deposits. b. Float as debris, scum or other matter to form nuisances. c. Produce objectionable odor, color, taste or turbidity. d. Result in the dominance of nuisance species.
Radioactive	Shall not exceed the recommended limits of the U.S. Environmental Protection Agency's National Drinking Water Regulations.
Tainting	Shall not be in concentrations or Substances combinations that produce undesirable flavors in the edible portions of aquatic organisms.
Color, Turbidity,	Shall not be in concentrations or Total Suspended combinations that would exceed the Solids recommended limits on the most sensitive receiving water use.
Oil and Grease	The water surface shall be free from floating oils, greases and petrochemicals and any concentrations in the water column or

	sediments that are aesthetically objectionable or deleterious to the biota are prohibited. For oil and grease of petroleum origin the maximum allowable discharge concentration is 15 mg/l.
Nutrients	Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication.
Other Constituents	Waters shall be free from pollutants in concentrations or combinations that: a. Exceed the recommended limits on the most sensitive receiving water use. b. Injure, are toxic to, or produce adverse physiological or behavioral responses in humans or aquatic life. c. Exceed site-specific safe exposure levels determined by bioassay using sensitive species.

TABLE 4

LIST OF PREVIOUS WATER QUALITY SURVEYS
MUDDY RIVER

Date	Agency*	Sampling Stations	Times Sampled
1974	MDWPC	6	4
1980	M&E, 1980	2	1
1986	MDWPC	20	1
1988	MWRA	3	1

*Legend

MDWPC	Massachusetts Division of Water Pollution Control
M&E, 1980	Metcalf & Eddy's Combined Sewer Overflow Facility Plan for Charles River Basin
MWRA	Massachusetts Water Resources Authority

Route 9 (exceedance of this value is generally considered a sign of polluted waters). Benthic demand for oxygen was also a factor in low DO levels due to the significant layer of organic matter existing in areas downstream from major storm drainage outlets below Route 9.

In most areas of the Muddy River, nutrient levels (table 6) were significantly in excess of those needed to provide excessive plant and algae growth in the quiescent Muddy River ponds. Total phosphorous levels ranged from 0.03 mg/l upstream to 0.11 mg/l downstream from Leverett Pond. Values greater than 0.3 mg/l were observed downstream from Route 9 and into the Back Bay Fens area. Significant nitrate levels were measured from a groundwater spring exiting the MDC skating rink area (2.3 mg/l) and almost the entire river had levels greater than 0.3 mg/l. In addition, significant levels of ammonia (a common sign of domestic sewage) were measured (greater than 1 mg/l) in the river near point discharges immediately downstream of Route 9. Ammonia levels in the Back Bay Fens area varied from 0.1 to nearly 0.5 mg/l. In comparison, as noted in the report, "Combined Sewer Overflow Facility Plan, Charles River Basin," dated 1980, by M&E, total phosphorous and total kjeldahl nitrogen (TKN) levels in the Fens were high with values of 0.34 mg/l and 2.6 mg/l, respectively. This report also states that average nutrient levels in the Fens were nearly twice those measured in the Charles River Basin.

Muddy River coliform levels (table 7) were perhaps the most indicative of domestic sewage, with fecal coliform levels exceeding 1,000 colonies/100 ml from Leverett Pond north to the Charles River during the September 1986 dry weather sampling. Another sampling event in July of the same year, showed evidence of raw sewage being discharged from an outlet pipe in the area near and just downstream from Route 9. The results are further substantiated by sampling undertaken in the Back Bay Fens for the 1980 M&E combined sewer overflows report, which showed evidence of combined sewer discharge occurring from the Boston gatehouses into the Back Bay Fens during a period of heavy rain in April 1979. The MWRA in their November 1988 cursory review of the status of combined sewer overflows, measured extremely high coliforms levels in the Longwood Avenue drain, and just downstream of the Tannery Brook drain. Both locations showed fecal coliform levels greater than 100,000 colonies/100 ml during a dry weather period indicating a serious cross connection problem.

The 1986 sampling revealed pH values (table 8) were just slightly over 7.0 standard units; hardness levels were less than 80 mg/l. Alkalinity values were generally greater than 30 mg/l, indicating that the river is somewhat protected from the acid rain phenomena. It was also pointed out in the report that the measurements were made during mid-day. This could be somewhat misleading for pH levels, since it is well known that most of the Muddy River is subject to significant algae growth. Algae growth tends to decrease carbon dioxide, an acidic gas, through photosynthesis during the day, and produce carbon dioxide during the night. This condition results in the diurnal fluctuation of pH. No diurnal evaluation of pH values was conducted in the 1986 survey. However, in the 1974 Massachusetts Division of Water Pollution Control survey, and in the 1980 combined sewer overflow study by M&E, significant diurnal fluctuation of pH values as well as DO levels were noted in the Back Bay

Fens area as rapid algae growth conditions produced significant daily changes.

The 1986 total and suspended solids (table 8) varied from 120 and 0.5 mg/l to over 280 and 43 mg/l, respectively. Although not a measure of true pollution, this indicated that levels were higher in the Fens than in the upper portion of the Muddy River. Even with essentially no water movement in the stagnant Back Bay Fens, settling of solids was not sufficient to produce lowered readings.

Metal levels (table 9 and 10) were generally below detectable limits, although the 1986 MADWPC report stated that further analysis needs to be completed to determine if values were less than levels needed to protect sensitive aquatic life. Iron and zinc were in the highest concentrations, ranging from 0.05 and 0.05 mg/l at the upper Muddy River to 0.7 and 0.02 mg/l, respectively, just below the Back Bay Fens. During a dry weather period in November 1978, and wet weather period during April 1979, metals were measured in the Back Bay Fens area for the 1980 M&E CSO report. Lead, copper and zinc were relatively low but exceeded limits set for protection of freshwater aquatic life. According to M&E's 1980 report, metal levels in the sediments in the Back Bay Fens are relatively high. With potential depletion of DO as a result of high organic loading in the Muddy River, there is potential for release of these metals from sediment through anaerobic action even if no further metals are discharged into the river.

Oil and grease levels (table 10) were elevated (above 15 mg/l) in a number of locations on the Muddy River and a light oil sheen was evident at almost all sites sampled for the 1986 report. An oil boom was in place at the upstream end of Willow Pond, indicating a recent oil spill.

d. <u>Corps of Engineers Water Quality Survey</u>

(1) <u>General</u>. A water quality sampling program to provide an update on current conditions for the Muddy River was completed by the Corps of Engineers during the summer of 1992. Water samples were collected for dry and wet weather events, from within the top 1 foot of the open Muddy River water column, a distance about 3 feet from shore. Due to the reconnaissance level nature of our study, there was no attempt to proceed upstream into the covered drainage system to further define apparent pollutant sources for either the wet or dry weather events.

Water quality analyses were performed for samples collected during a dry weather period on 24 June, with 13 different sites sampled along the entire length of the river. Because of a problem in analyzing coliform data collected for the first event, an additional partial round of sampling was completed at the same locations on 1 September, in an effort to develop coliform data for a dry weather condition. There was no rain for the preceding three days prior to either collection.

Ideal design of a wet weather sampling event includes; a prerequisite detailed

TABLE 5

TEMPERATURE - DO - SATURATION

1986 MUDDY RIVER - BACK BAY FENS SURVEY
MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

9/10/86

STATION NUMBER	TIME (hr)	TEMPERATURE (°F)	D.O. (mg/l)	% SATURATION
MR01	1010	68	8.9	96.8
MR02	1016	66	7.2	76.7
MR03	1028	61	7.5	75.5
MR04	1029	56	7.5	71.2
MR05	1038	60	10.1	100.6
MR06	1049	67	8.8	94.7
MR07	1100	67	9.4	101.2
MR08	1106	67	9.2	99.0
MR09	1116	66	9.1	96.9
MR10	1130	67	6.7	72.1
MR11	1130	66	6.2	66.0
MR12	1140	66	8.2	87.3
MR13	1155	66	6.6	70.3
MR14	1215	67	5.5	59.2
MR15	1230	65	2.6	27.4
MR16	1238	68	8.1	88.1
MR17	1238	67	4.3	46.3
MR18	1310	68	4.5	49.0
MR19	1300	67	7.2	77.5
MR20	1327	67	5.5	59.2

TABLE 6

TOTAL AND FECAL COLIFORM

1986 MUDDY RIVER - BACK BAY FENS SURVEY
MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

	7/24/86		9/10/86
STATION NUMBER	TOTAL COLIFORM	FECAL COLIFORM	FECAL COLIFORM
MR01	—	—	20
MR02	—	—	<5
MR03	—	—	800
MR04	—	—	300
MR05	—	—	100
MR06	—	—	140
MR07	10,000	500	3,000
MR08	15,000	900	1,500
MR09	400,000	30,000	6,000
MR10	—	—	7,000
MR11	150,000	14,000	2,500
MR12	200,000	15,000	4,000
MR13	—	—	3,600
MR14	—	—	1,500
MR15	—	—	700
MR16	—	—	<5
MR17	—	—	12,000
MR18	—	—	2,600
MR19	—	—	600
MR20	—	—	240

TABLE 7

BOD_5 - TKN - NITRATE - TOTAL PHOSPHOROUS - ORTHOPHOSPHOROUS

1986 MUDDY RIVER - BACK BAY FENS SURVEY
MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

9/10/86

(All results in mg/l)

STATION NUMBER	BOD_5	TOTAL KJELDAHL-NITROGEN	AMMONIA-NITROGEN	NITRATE-NITROGEN	TOTAL PHOSPHORUS	ORTHO-PHOSPHORUS
MR01	1.8	0.90	0.08	0.2	0.06	0.02
MR02	0.6	0.48	0.05	<0.1	0.03	0.01
MR03	0.9	0.51	0.06	0.5	0.04	0.03
MR04	0.9	0.41	0.06	2.3	0.03	0.01
MR05	0.9	0.41	0.05	0.9	0.04	0.02
MR06	0.3	0.52	0.07	0.9	0.06	0.02
MR07	2.4	0.84	0.23	0.4	0.12	0.07
MR08	1.8	0.75	0.20	0.3	0.11	0.05
MR09	3.0	0.66	0.21	0.3	0.14	0.06
MR10	5.1	1.6	1.0	0.3	0.48	0.29
MR11	2.4	0.98	0.25	0.4	0.15	0.07
MR12	3.3	1.2	0.47	0.3	0.24	0.12
MR13	3.0	0.84	0.41	0.3	0.21	0.10
MR14	5.7	1.1	0.40	0.4	0.36	0.06
MR15	3.3	0.78	0.33	0.6	0.18	0.09
MR16	1.2	0.56	0.10	0.5	0.12	0.07
MR17	3.6	0.94	0.57	0.6	0.30	0.19
MR18	1.5	0.81	0.44	0.5	0.26	0.17
MR19	3.3	1.1	0.25	0.3	0.26	0.14
MR20	3.6	0.84	0.26	0.4	0.19	0.10

TABLE 8

pH - ALKALINITY - HARDNESS - CHLORIDE - SUSPENDED SOLIDS - DISSOLVED SOLIDS

1986 MUDDY RIVER - BACK BAY FENS SURVEY
MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

9/10/86

STATION NUMBER	pH*	ALKALINITY	HARDNESS	CHLORIDE	SUSPENDED SOLIDS	TOTAL SOLIDS
MR01	7.7	17	31	60	3.5	210
MR02	7.1	31	51	70	2.5	226
MR03	7.0	32	44	57	1.5	200
MR04	6.8	41	80	110	1.5	362
MR05	7.2	34	62	80	0.5	248
MR06	7.1	43	68	90	2.5	286
MR07	7.4	17	32	34	4.0	126
MR08	7.4	34	33	36	3.5	138
MR09	7.4	28	32	36	6.5	148
MR10	7.1	42	51	53	6.0	208
MR11	7.3	25	35	39	6.0	154
MR12	7.1	31	37	49	4.5	176
MR13	7.2	30	41	44	11	172
MR14	7.2	32	49	47	43	226
MR15	7.2	46	40	47	5.5	176
MR16	7.4	32	44	50	2.5	194
MR17	7.3	30	50	58	4.0	210
MR18	7.3	44	49	65	7.0	216
MR19	7.3	36	49	57	11	226
MR20	7.3	47	50	58	8.0	214

* Results in standard units

TABLE 9

ALUMINUM - CADMIUM - CHROMIUM - COPPER - IRON

1986 MUDDY RIVER - BACK BAY FENS SURVEY
MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

9/10/86

(All results in mg/l)

STATION NUMBER	ALUMINUM	CADMIUM	CHROMIUM	COPPER	IRON
MR01	<0.10*	<0.02	<0.03	<0.02	0.05
MR02	<0.10	<0.02	<0.03	<0.02	0.12
MR03	<0.10	<0.02	<0.03	<0.02	0.26
MR04	<0.10	<0.02	<0.03	<0.02	<0.04
MR05	<0.10	<0.02	<0.03	<0.02	0.20
MR06	<0.10	<0.02	<0.03	<0.02	0.26
MR07	<0.10	<0.02	<0.03	<0.02	0.27
MR08	<0.10	<0.02	<0.03	<0.02	0.30
MR09	<0.10	<0.02	<0.03	<0.02	0.27
MR10	<0.10	<0.02	<0.03	<0.02	0.39
MR11	<0.10	<0.02	<0.03	<0.02	0.29
MR12	<0.10	<0.02	<0.03	<0.02	0.32
MR13	<0.10	<0.02	<0.03	<0.02	0.38
MR14	0.20	<0.02	<0.03	<0.02	0.54
MR15	<0.10	<0.02	<0.03	<0.02	0.35
MR16	<0.10	<0.02	<0.03	<0.02	0.29
MR17	<0.10	<0.02	<0.03	<0.02	0.44
MR18	<0.10	<0.02	<0.03	<0.02	0.71
MR19	<0.10	<0.02	<0.03	<0.02	0.72
MR20	<0.10	<0.02	<0.03	<0.02	0.44

*<level of detection

TABLE 10

LEAD - NICKEL - SILVER - ZINC - OIL & GREASE

1986 MUDDY RIVER - BACK BAY FENS SURVEY
MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

(All results in mg/l)

STATION NUMBER	LEAD	NICKEL	SILVER	ZINC	OIL & GREASE
MR01	<0.05*	<0.05	<0.02	0.05	--
MR02	<0.05	<0.05	<0.02	0.05	--
MR03	<0.05	<0.05	<0.02	0.05	--
MR04	<0.05	<0.05	<0.02	<0.02	--
MR05	<0.05	<0.05	<0.02	0.07	1.8
MR06	<0.05	<0.05	<0.02	0.03	--
MR07	<0.05	<0.05	<0.02	0.02	--
MR08	<0.05	<0.05	<0.02	0.02	--
MR09	<0.05	<0.05	<0.02	0.02	16
MR10	<0.05	<0.05	<0.02	0.03	63
MR11	<0.05	<0.05	<0.02	<0.02	--
MR12	<0.05	<0.05	<0.02	0.02	--
MR13	<0.05	<0.05	<0.02	<0.02	--
MR14	<0.05	<0.05	<0.02	0.03	35
MR15	<0.05	<0.05	<0.02	0.04	--
MR16	<0.05	<0.05	<0.02	0.02	--
MR17	<0.05	<0.05	<0.02	0.02	--
MR18	<0.05	<0.05	<0.02	<0.02	--
MR19	<0.05	<0.05	<0.02	0.02	--
MR20	<0.05	<0.05	<0.02	0.02	0.0

* <level of detection

hydrologic and basin characteristic study of the drainage area to determine the best place and time to make measurements of flows and pollutants, the devel- opment of a rainfall distribution pattern for the sampling event, and a sufficient number of sampling and flow measurement events within the drainage system and receiving water to determine shape of the flow versus time and pollutant versus time relationships. This data can then be used to develop a computer model of the drainage system and determine its impact on receiving water.

Since this is only an initial reconnaissance investigation, and more comprehensive feasibility studies would be needed if Corps efforts proceed, there was no ideal implementation of a wet weather sampling event. A simplistic approach of gathering a single grab sample at 12 sampling sites, after a small rainstorm, was used to provide a rough estimate of wet weather characteristics within the Muddy River receiving water. Collection of wet weather water quality samples took place on 14 August after approximately 0.5 inch of rain fell in a 4 to 6 hour period in the Boston area. The 12 sites were sampled within 6 to 8 hours after the storm. Eleven samples were gathered in the same locations as the dry weather sites, and an additional one was gathered opposite Aspinwall Street, just downstream from the Tannery Brook Drain.

Locations of the water quality sampling sites are described in table 11 and shown in plate C-6. Tables 12 through 32 summarize dry and wet weather data.

The following sections discuss specific water quality parameters and their implications on the overall water quality conditions of the river.

(2) __Dissolved Oxygen__. During the 24 June 1992 dry weather sampling, dissolved oxygen levels (table 12) in the Muddy River were above standards to protect warm water fisheries from the Jamaica Pond area downstream to the Route 9 bridge. Values varied from 8.9 mg/l at Jamaica Pond to 5.9 mg/l in the river just upstream from Willow Pond, then rising to levels in the 7 and 8 mg/l range near Route 9. As dry weather discharges from the Tannery Brook storm drain and others enter the river, organics settle out and benthic oxygen demand of the thick sediment layer takes effect, with DO levels decreasing significantly. Within 800 feet of the 7.3 mg/l reading, just downstream from Route 9, the DO level dropped to 3.3 mg/l, and falling further to 1.0 mg/l just upstream from the Longwood Avenue bridge. Surface level readings throughout the Back Bay Fens continue to be generally below Class B standard with readings in the 1 to 2 mg/l range.

DO measurements can vary throughout the day as a result of algae production and respiration. The algae will produce oxygen during the day through photosynthesis, and will use up oxygen during the night through respiration. Although diurnal variation was not measured, one can be sure that the DO levels will vary in the highly eutrophic conditions of the Back Bay Fens. Biochemical oxygen demand (BOD) levels on 24 June 1992 (table 13) were below 6 mg/l. Total organic carbon levels (table 14) varied from 4.0 mg/l at Leverett Pond to 8.8 mg/l at the lower Fens. Water temperature readings (table 15) ranged from 63 to 70 °F (17.5 to 21.0 °C).

TABLE 11
LOCATION OF CORPS OF ENGINEERS
WATER QUALITY SAMPLING STATIONS
MUDDY RIVER - 1992

Station	River Mile Above Charles River	Description
W-1	3.5	Outlet of Jamaica Pond, approx. 30 feet from shore. (D)
W-2	3.2	Inlet to Willow Pond, 50 feet upstream from footbridge. (D)
W-3	3.1	Inlet to Leverett Pond, 50 feet upstream from footbridge(W,D)
W-5	2.8	Downstream end of Leverett Pond, 50 feet upstream from bridge. (W,D)
W-6	2.6	Downstream side of Route 9 bridge. (W,D)
W-7	2.5	Opposite Aspinwall Street. (W)
W-8	2.4	50 feet upstream of Brookline Avenue bridge. (W,D)
W-9	2.3	50 feet upstream of Netherlands Road bridge. (W,D)
W-10	2.1	50 yds. upstream of Longwood Avenue. (W,D)
W-11	1.7	50 feet upstream of Park Drive bridge. (W,D)
W-12	1.3	25 yards below bridge near Louis Pasteur Avenue. (W,D)
W-13	0.9	30 yards upstream of footbridge near Forsyth Way. (W,D)
W-14	0.7	Immediately upstream of Agassiz Road bridge. (W,D)
W-15	0.4	Immediately upstream of Boylston St. bridge. (W,D)

*Legend

W - Wet weather sample collected 14 August 1992
D - Dry Weather sample collected 24 June 1992 or 1 September 1992

TABLE 12
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

DISSOLVED OXYGEN (mg/l)

Station	24 June*	14 August**	1 Sept
W-1	8.9	---	7.9
W-2	5.9	---	8.2
W-3	7.5	7.0	6.7
W-5	8.5	7.8	7.5
W-6	7.3	8.2	7.6
W-7	---	6.3	--
W-8	3.3	6.1	6.1
W-9	1.8	4.7	4.9
W-10	1.0	3.0	3.1
W-11	1.3	0.9	2.9
W-12	1.7	0.7	1.5
W-13	1.6	0.7	2.6
W-14	2.5	1.2	2.9
W-15	3.7	3.8	3.6

TABLE 13
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

BIOCHEMICAL OXYGEN DEMAND (BOD)
(mg/l)

Station	24 June*	4 August**	Station	24 June*	4 August**
W-1	< 6	--	W-9	< 6	5
W-2	< 6	--	W-10	< 6	< 6
W-3	< 6	< 6	W-11	< 6	< 6
W-5	< 6	< 6	W-12	< 6	< 6
W-6	< 6	6	W-13	< 6	32
W-7	---	7	W-14	< 6	26
W-8	< 6	10	W-15	< 6	< 6

* Dry weather
** Wet Weather

TABLE 14
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

TOTAL ORGANIC CARBON (mg/l)

Station	24 June*	14 August**	Station	24 June*	14 August**
W-1	---	---	W-9	---	---
W-2	---	---	W-10	---	---
W-3	---	6.0	W-11	7.4	7.1
W-5	4.0	6.9	W-12	6.3	---
W-6	---	---	W-13	7.0	6.5
W-7	---	8.3	W-14	8.8	6.9
W-8	7.0	8.2	W-15	---	---

* Dry Weather ** Wet Weather

TABLE 15

MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS
TEMPERATURE
(Degrees Celsius)

Station	24 June*	14 August**	1 Sept
W-1	19.4	----	21.0
W-2	19.6	----	18.1
W-3	17.5	16.4	14.2
W-5	18.0	17.5	18.1
W-6	17.6	17.9	18.1
W-7	----	18.1	----
W-8	18.1	18.0	18.0
W-9	18.3	18.1	18.1
W-10	18.6	14.5	18.2
W-11	18.9	19.0	18.7
W-12	19.3	19.4	19.0
W-13	19.6	19.9	18.8
W-14	19.4	20.2	19.4
W-15	21.0	20.7	20.6

* Dry weather ** Wet Weather

Dry weather DO measurements made on 1 September 1992, also show low values, with the same areas below Route 9 generally showing DO levels less than 5.0 mg/l. DO values did not drop as quickly in the area below Tannery Brook Drain possibly indicating impacts from recent removal of one town of Brookline sewer cross connection from the upstream drainage system. Values, however, did continue to fall to the 1 to 3 mg/l range as the river approached the Back Bay Fens. Water temperature readings for 1 September generally ranged from 64 to 70 °F (18.1 to 21.0 °C).

Wet weather measurement of DO showed similar results with levels dropping below the 5.0 mg/l standard downstream from Brookline Avenue, and remaining below that level throughout the lower portion of the river, nearly becoming anoxic in the Back Bay Fens (0.7 mg/l). Wet weather storm drainage runoff near the Tannery Brook discharge kept DO levels above 6.0 mg/l at least temporarily. BOD levels were shown to increase above 6 mg/l downstream from Tannery Brook Drain, possibly as a result of releases from the storm drain, or as a result of resuspension of the organic bottom sediment in this narrow part of the river. BOD levels increased signifi- cantly in the local area upstream and downstream from the Boston gatehouses in the Back Bay Fens, possibly as a result of storm drain releases and overland runoff in the park. It is uncertain whether 0.5-inch of rainfall would have resulted in a combined sewer release from these gatehouses. Total organic carbon levels varied from 6.0 mg/l just upstream from Leverett Pond to 8.3 mg/l just downstream from the Tannery Brook Drain. Water temperatures within the river varied from 62 to 69 °F (16.4 to 20.7 °C) showed the impact of cooler rainfall (air temperature on that day approximately 60 degrees Fahrenheit).

(3) Nutrients. Nutrient values were generally above those needed for rapid algae growth in the river in almost all areas below Jamaica Pond although it wasn't until just downstream from the Tannery Brook drain that values really became significantly higher.

During dry weather, nitrate levels (table 16) were below 0.15 mg/l upstream from Leverett Pond, increasing to 0.37 mg/l near the pond's outlet, and rising to 0.45 mg/l just downstream of Tannery Brook Drain (water quality sampling site W-8). At least during dry weather, there did not appear to be a major source of nitrates coming from the underground spring located near the MDC skating rink, a problem area in earlier surveys. During dry weather, the increase in nitrates from upstream of Willow Pond (water quality station, W-2) to downstream (W-3) was minor (0.084 to 0.15 mg/l, respectively). However, the wet weather sample collected upstream from Leverett Pond showed a significant level of nitrates (1.9 mg/l), indicating that wet weather may have increased discharge from the underground spring near the MDC skating rink. Nitrate values began dropping after Brookline Avenue (W-8) for both dry and wet weather sampling, possibly due to algae and vegetation, using the nitrates for food but also possibly as a result of anaerobic benthic activity which would strip the oxygen from the nitrate, releasing nitrogen in most cases, ammonia in others. The values decreased to less than 0.03 mg/l. Nitrite values were less than 0.03 mg/l at all stations during dry weather, and less than 0.08 mg/l during wet weather.

Nitrogen found in raw wastewater is generally in organic nitrogen and ammonia forms. Organic nitrogen is readily decomposed to ammonia through bacterial action. Total kjeldahl nitrogen (TKN - a measure of nitrogen in the organic and ammonia forms) was measured at 7 stations during dry weather from Jamaica Pond to the lower Fens, and 5 stations during wet weather from Leverett Pond to the Fens (table 17). Dry weather results, ranging from 0.8 mg/l upstream from Willow Pond to 9.1 mg/l at Boylston Street in the Fens, generally show a steady increase in concentration as one proceeds downstream. There was a significant increase measured downstream from Tannery Brook Drain and also downstream from Boston Gatehouse Nos. 1 and 2. Wet weather results were lower, showing the effects of runoff dilution, with levels ranging from 0.5 mg/l at Leverett Pond to 2.3 mg/l in the Fens. Wet weather sampling shows a similar tendency of increasing TKN when proceeding downstream.

Ammonia levels (table 18) from 13 dry weather stations show similar tendencies as TKN, with values ranging from less than 0.02 at Jamaica Pond to 4.9 mg/l in the Fens just upstream from the Boston gatehouses. There is no increase in ammonia downstream of the gatehouses, possibly indicating that the high TKN reading may be an anomaly, or possibly plant matter may have been included in the analyzed sample. In any event, it is important to note that ammonia levels jumped significantly immediately downstream of Tannery Brook Drain (from 0.22 to 3.6 mg/l) and remained high throughout the Fens area. There was also a slight increase in ammonia levels in the Muddy River just upstream from the Brookline Avenue Gatehouse (W-11). There could be an added source of raw sewage in this area also, possibly the Longwood Avenue Drain. The 12 wet weather samples mirror dry weather results; however, the concentrations are not as high because of the runoff dilution effect. Wet weather values range from 0.18 mg/l at Willow Pond, jumping to 0.77 mg/l downstream from Tannery Brook Drain, and rising again to 1.6 mg/l upstream from the Brookline Avenue Gatehouse, before peaking at 2.1 mg/l just downstream from the Boston gatehouses in the Fens.

Total phosphorous and orthophosphate levels (table 19) were measured in all 13 dry weather locations and all 12 wet weather sites. Orthophosphate is the form of phosphorous which can readily be assimilated by plants. Phosphorous is usually the nutrient in shortest supply, and becomes the limiting factor in plant growth, since nitrogen can be acquired from the atmosphere by nitrifying bacteria. Generally, phosphorous levels need to be as high as 0.05 mg/l in a flowing river to become a problem, causing rapid algae growth. In more quiescent ponds, levels can be as low as 0.015 mg/l to produce rapid algae growth.

Phosphorous levels were generally above 0.015 mg/l throughout the entire length, and above 0.05 mg/l from the lower end of Leverett Pond down to the end of the Fens during both dry and wet weather. This indicates that phosphorous would not be a limiting factor to rapid algae growth in any portion of the Muddy River. Dry weather phosphorous levels varied from 0.015 to 0.072 mg/l at the downstream side of the Route 9 bridge, with a minor increase occurring in the Leverett Pond area (possibly resulting from discharge of the Village Brook

TABLE 16
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

NITRATE - NITRITE
(mg/l as N)

	24 June*		14 August**	
Station	Nitrate	Nitrite	Nitrate	Nitrite
W-1	0.098	<0.030	----	-----
W-2	0.084	<0.030	----	-----
W-3	0.15	<0.030	1.9	<0.030
W-5	0.37	<0.030	0.54	0.026
W-6	0.37	<0.030	0.42	0.024
W-7	----	-----	0.78	0.043
W-8	0.45	<0.030	0.86	0.04
W-9	0.23	<0.030	0.42	0.079
W-10	0.14	<0.030	0.38	<0.030
W-11	<0.030	<0.030	0.18	0.029
W-12	0.058	<0.030	0.096	0.028
W-13	<0.030	<0.030	0.026	0.037
W-14	0.033	<0.030	0.014	<0.030
W-15	0.047	<0.030	0.034	0.032

*Dry weather **Wet weather

TABLE 17
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS
TOTAL KJELDAHL NITROGEN (TKN)
(mg/l as N)

Station	24 June*	14 August**	Station	24 June*	14 August**
W-1	1.3	---	W-9	---	---
W-2	0.8	---	W-10	---	---
W-3	---	---	W-11	3.7	2.1
W-5	1.5	0.5	W-12	---	---
W-6	---	---	W-13	4.9	2.3
W-7	--	---	W-14	---	2.0
W-8	3.7	1.4	W-15	9.1	---

* Dry weather ** Wet weather

TABLE 18
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

AMMONIA
(mg/l as N)

Station	24 June*	14 August**	Station	24 June*	14 August**
W-1	<0.02	----	W-9	3.4	0.82
W-2	0.056	----	W-10	2.9	1.2
W-3	0.034	0.18	W-11	3.7	1.6
W-5	0.17	0.35	W-12	4.4	1.8
W-6	0.22	0.39	W-13	4.9	2.0
W-7	----	0.77	W-14	4.7	2.1
W-8	3.6	0.70	W-15	4.4	1.4

* Dry weather ** Wet weather

TABLE 19
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS
TOTAL PHOSPHOROUS - ORTHOPHOSPHATE
(mg/l)

	24 June*		14 August**	
Station	Total Phosphorous	Ortho Phosphate	Total Phosphorous	Ortho Phosphate
W-1	0.015	<0.060	----	----
W-2	0.034	<0.060	----	----
W-3	0.028	<0.060	0.49	<0.030
W-5	0.058	<0.060	0.59	0.036
W-6	0.072	<0.060	0.14	0.036
W-7	----	----	0.16	0.18
W-8	0.48	0.21	0.16	0.13
W-9	0.49	0.26	0.18	0.14
W-10	0.52	0.25	0.20	0.048
W-11	0.66	0.32	0.21	0.065
W-12	0.72	0.26	0.29	0.071
W-13	0.60	0.27	0.42	0.18
W-14	0.53	0.23	0.03	0.15
W-15	0.51	0.25	0.13	0.19

* Dry weather ** Wet weather

Drain). After the Tannery Brook Drain, dry weather phosphorous levels jumped significantly, rising to 0.48 mg/l immediately, and rising even higher to 0.72 mg/l after the Brookline Avenue Gatehouse, indicating another source of sewage (other than the Tannery Brook Drain) was entering in the area near the Gatehouse (possibly the Longwood Avenue Drain). Orthophosphate levels ranged from less than 0.06 to 0.32 mg/l, again showing the large jump in concentration after entrance of the Tannery Brook Drain. Wet weather total phosphorous results generally showed dilution impacts of runoff. However, in the area between Willow Pond and the Route 9 bridge, wet weather concentrations were higher (Stations W-3 and W-5). These higher concentrations may result from surface runoff of fertilizer in the parkland, or possibly release of nutrients by scouring sewage sludge from upstream cross connected storm drains.

(4) <u>Coliform</u>. Total and fecal coliform measurements (tables 20 and 21) were made during dry weather conditions on 24 June 1992, and because of an inadequate detection limit, were measured again on 1 September 1992. Fecal coliform measurements were generally above Class B standards of 200 colonies/100ml at all times from the downstream end of Leverett Pond to the Back Bay Fens, just upstream from the Boston gatehouses. Readings exceeded the standards for nearly all stations (with the exception of Jamaica Pond) for at least one of the sampling days. According to the 1 September data, significant jumps in fecal coliform levels occurred at the lower end of Leverett Pond and significant levels were maintained downstream from the Route 9 bridge. Quantities began to decrease after those areas, mostly due to dilution effects; however, there may be some bacterial die-off or reduction due to natural processes (i.e., sunlight, sedimentation, biological flocculation and precipitation, bacterial predators, etc.). Numbers of fecal and total coliform ranged from less than 100 colonies/100 ml for both, to 18,000 colonies/100 ml and 110,000 colonies/100 ml, respectively.

Total and fecal coliform measurements were made during wet weather conditions on 14 August 1992. Both total and fecal coliform concentrations were significantly higher than dry weather measurements, especially in the area from the Route 9 bridge down to the upper end of the Back Bay Fens, near Louis Pasteur Avenue. There appeared to be a significant sewage discharge occurring from the Tannery Brook Drain. There also seemed to be an apparent increase in coliform releases downstream from the Muddy River Conduit diversion (W-12). This source of contamination may be due to backwater from the Muddy River Conduit, which receives combined sewer overflow, or possibly from another source (i.e., Emmanuel College Drain). In either case, this section of the Muddy River needs further investigation. There was essentially no change in the Back Bay Fens area from dry weather measurements, showing no likely combined sewer overflow at the Boston gatehouses and indicating that coliform from upstream reaches die-off before they reach this area.

(5) <u>pH</u>. On 24 June and 1 September 1992, pH was measured during dry weather conditions for all 13 stations, and at 12 stations during wet weather conditions on 14 August (table 22).

During dry weather, pH varied from approximately 8.0 standard units in the upper Muddy River area (Ward's and Jamaica Ponds), to 6.0 and less in the Back Bay Fens area. The higher readings in Jamaica and Ward's Ponds, in the absence of a known industrial discharge, are likely the result of significant algae activity, which uses up naturally occurring carbonic acid as carbon dioxide is removed during photosynthesis. These pH levels will vary diurnally since night time respiration of the algae will use up oxygen and produce carbon dioxide. The pH levels in the lower Muddy River, particularly below Route 9 on 24 June 1992, show the effects heavy sludge deposits have in releasing acids during anaerobic benthic activity.

During wet weather measurements, pH showed less variation than the dry weather event, with values ranging from 6.2 through 6.6. The narrower range may result from rainfall runoff influence on the river.

(6) __Solids__. Total, suspended, and dissolved solids measurements (table 23) were made during dry and wet weather in the Muddy River. As can be expected from such a slow moving water body, where settling occurs rapidly, there were very low suspended solids within the water column during dry weather. However, suspended solids tended to increase beginning at the lower end of Leverett Pond, possibly due to an increase in dry weather discharge from storm drains, or possibly due to measurements of increased algae numbers. During wet weather, suspended solids showed increases at nearly all the stations measured, with values exceeding 19 mg/l at two different stations. Dissolved solids ranged from 118 to 300 mg/l, and total solids ranged from 132 to 303 mg/l for dry and wet weather conditions. Chloride concentration (table 24) ranged from 33 to 73 mg/l for dry and wet weather sampling events showing the effect the old and new Charles River Dams had on eliminating saltwater intrusion into the Muddy River. Specific conductivity (table 25) varied from 106 to 560 micromhos/cm during dry and wet weather, with generally the highest readings taking place in dry weather conditions.

(7) __Hardness and Alkalinity__. Hardness and alkalinity measurements (table 26) were made at several stations on the Muddy River during dry and wet weather. Hardness measurements showed the river to have soft waters, with hardness ranging from 40 to 64 mg/l during dry weather, and lower values of 19 through 54 mg/l reflecting dilution during wet weather. Dry weather alkalinity in the river was low, with values ranging from 12 mg/l at Jamaica Pond to 54 mg/l in the Back Bay Fens. Wet weather alkalinity ranged from 15 to 43 mg/l, the trend likely showing the result of acid rain phenomena.

(8) __Oil and Grease__. Oil and grease measurements (table 27) made throughout the length of the river during dry weather show the impacts of significant paved urban areas. Values were less than 0.15 mg/l in Leverett Pond and up- stream; however, they ranged from 0.17 to 3.5 mg/l downstream of the Route 9 bridge, with the highest slug of oil appearing at the Tannery Brook Drain area (3.5 mg/l). Wet weather results, although showing dilution, indicate similar effects with values ranging from 0.15 to 1.6 mg/l; one exception being a reading of 30 mg/l located just upstream from Leverett Pond. This high value was probably

TABLE 20
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

TOTAL COLIFORM
(Colonies/100 ml)

Station	24 June*	14 August**	1 Sept
W-1	1880	-----	29
W-2	1520	-----	9400
W-3	3200	27000	1700
W-5	>3200	19000	18000
W-6	>3200	280000	32000
W-7	----	760000	-----
W-8	>3200	1600000	100000
W-9	>3200	1300000	110000
W-10	>3200	470000	60000
W-11	>3200	73000	6300
W-12	>3200	120000	7700
W-13	>3200	43	2300
W-14	>3200	4200	650
W-15	1680	106	100

* Dry weather ** Wet weather

TABLE 21
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

FECAL COLIFORM
(Colonies/100 ml)

Station	24 June*	14 August**	1 Sept
W-1	60	-----	29
W-2	300	-----	800
W-3	>1200	6400	145
W-5	2000	850	3000
W-6	1680	25000	18000
W-7	----	490000	-----
W-8	1200	460000	8500
W-9	>1200	390000	8200
W-10	>1200	46000	4600
W-11	>1200	24000	580
W-12	>1200	37000	500
W-13	>1200	43	290
W-14	50	195	140
W-15	1070	100	50

* Dry weather ** Wet weather

TABLE 22
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

pH
(Standard Units)

Station	24 June*	14 August**	1 Sept
W-1	7.7	---	8.0
W-2	6.7	---	7.7
W-3	7.0	6.5	7.2
W-5	6.8	6.6	7.3
W-6	6.5	6.6	6.8
W-7	---	6.4	---
W-8	6.2	6.3	7.0
W-9	6.3	6.2	6.8
W-10	6.1	6.4	6.5
W-11	6.3	6.2	6.4
W-12	6.1	6.2	6.5
W-13	6.1	6.2	5.2
W-14	6.2	6.2	6.6
W-15	6.2	6.3	6.6

* Dry weather ** Wet weather

TABLE 23

MUDDY RIVER

CORPS OF ENGINEERS

1992 WATER QUALITY SAMPLING RESULTS

TOTAL SOLIDS, TOTAL DISSOLVED SOLIDS, SUSPENDED SOLIDS

(mg/l)

	24 June*			14 August**		
Station	TS	TDS	SS	TS	TDS	SS
W-1	172	171	1.2	---	---	---
W-2	218	217	1.3	---	---	---
W-3	208	207	1.5	303	300	3.2
W-5	140	133	7.1	155	146	8.7
W-6	148	141	7.1	132	118	14.0
W-7	---	---	---	191	183	8.8
W-8	216	208	7.5	176	156	19.7
W-9	300	293	7.2	163	152	10.9
W-10	192	187	5.4	232	224	7.9
W-11	220	214	6.4	246	240	6.0
W-12	210	204	6.3	242	230	12.0
W-13	214	206	7.6	185	178	6.8
W-14	236	213	23	242	214	27.6
W-15	218	214	4.2	181	178	2.7

* Dry weather ** Wet weather

TABLE 24

MUDDY RIVER

CORPS OF ENGINEERS

1992 WATER QUALITY SAMPLING RESULTS

CHLORIDE

(mg/l)

Station	24 June*	14 August**	Station	24 June*	14 August**
W-1	62	--	W-9	--	--
W-2	--	--	W-10	--	--
W-3	68	--	W-11	62	55
W-5	39	37	W-12	--	--
W-6	40	33	W-13	--	--
W-7	--	72	W-14	59	37
W-8	56	73	W-15	60	44

* Dry weather ** Wet weather

TABLE 25
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

SPECIFIC CONDUCTIVITY
(Micromhos/cm)

Station	24 June*	14 August**	1 Sept	Station	24 June*	14 August**	1 Sept
W-1	273	---	305	W-9	284	167	269
W-2	302	---	115	W-10	285	232	278
W-3	303	363	560	W-11	322	298	323
W-5	207	126	245	W-12	223	298	309
W-6	209	106	233	W-13	316	235	318
W-7	---	163	---	W-14	110	225	337
W-8	300	146	274	W-15	319	249	337

* Dry weather ** Wet weather

TABLE 26
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS
HARDNESS--ALKALINITY
(mg/l as $CaCO_3$)

	24 June*		14 August**	
Station	Hardness	Alkalinity	Hardness	Alkalinity
W-1	40	12	--	--
W-2	--	--	--	--
W-3	--	--	--	--
W-5	45	29	19	15
W-6	--	--	--	--
W-7	--	--	--	--
W-8	--	--	--	--
W-9	59	38	--	22
W-10	--	--	--	--
W-11	64	46	54	43
W-12	--	--	--	--
W-13	--	--	--	--
W-14	63	54	42	33
W-15	63	51	48	30

* Dry weather ** Wet weather

TABLE 27
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

OIL AND GREASE
(mg/l)

Station	24 June*	14 August**	Station	24 June*	14 August**
W-1	<0.13	---	W-9	1.6	1.6
W-2	<0.15	---	W-10	---	---
W-3	<0.15	30	W-11	1.7	0.33
W-5	0.28	0.83	W-12	0.92	0.17
W-6	0.20	1.6	W-13	0.64	0.22
W-7	---	1.2	W-14	0.57	0.15
W-8	3.5	1.5	W-15	0.17	0.31

* Dry weather ** Wet weather

TABLE 28
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

POLYCHLORINATED BIPHENYLS (PCB)
(ppb)

Station	24 June*	14 August**	Station	24 June*	14 August**
W-1	-----	-----	W-9	-----	-----
W-2	-----	-----	W-10	-----	-----
W-3	-----	-----	W-11	<0.063	<0.056
W-5	-----	-----	W-12	-----	-----
W-6	-----	-----	W-13	-----	-----
W-7	-----	-----	W-14	<0.076	-----
W-8	-----	-----	W-15	-----	-----

* Dry weather ** Wet weather

the result of oil being washed over the oil boom which is located at the upstream end of Willow Pond. Three spot checks on PCB levels (table 28) in the water column in the Fens showed levels below 0.076 ppb.

(9) Algae. Three locations during dry weather and two during wet weather were sampled for algae (count and general species identification, see table 29). The first area (W-5) was near the outlet of Leverett Pond, the second was just upstream from the Brookline Avenue Gatehouse, and the third or most downstream area, was just upstream from Boston Gatehouse Nos. 1 and 2. All samples were less than 1,000 units/ ml, the approximate lower level indicator of a significant algae bloom condition. Wet weather samples were significantly less than the dry weather samples indicating either dilution or the result of cloudy and cool weather, which was typical of our 1992 summer. During dry weather sampling, the upper station showed a majority of the organisms were diatoms with green and blue-green algae (an indicator of pollution), becoming more prevalent when proceeding downstream. The wet weather sample showed increases in blue- green algae from the upper to the lower area.

(10) Metals. Various metal measurements (tables 30, 31, and 32) were made throughout the entire length of the river on 24 June and 14 August. All heavy metals measured, with the exception of zinc and iron during dry weather and zinc, iron, copper, and lead during wet weather, were near or below detectable limits developed for the conducted analysis. Arsenic, chromium, and nickel levels were below detectable limits, which in turn were less than 24-hour chronic criteria limits set to protect sensitive aquatic life (see table 33 for EPA criteria). Cadmium and copper levels during dry weather and cadmium levels during wet weather, were less than detectable limits, which are higher than the 24-hour and maximum limit established to protect sensitive aquatic life. Wet weather measurement of copper was higher than the maximum limit to protect aquatic life at all stations from Leverett Pond to the Brookline Avenue Gatehouse. Further analysis and investigation, with lower detection limits, is needed for both cadmium and copper. Mercury levels were generally less than detectable limits (0.0004 mg/l), which is higher than the 24- hour limit but less than the maximum limit established to protect sensitive aquatic life. Further analysis may be needed for this metal. Zinc levels during dry and wet weather generally varied from above 0.047 to 0.15 mg/l, which is greater than the 24-hour chronic toxicity limit to protect sensitive aquatic life (0.047 mg/l), but is less than the maximum limit (0.165 mg/l) set to protect sensitive aquatic life. Iron levels during dry and wet weather varied from 0.14 to 1.7 mg/l, which are significantly less than the 1,000 mg/l maximum limit set to protect sensitive aquatic life.

e. Results of the Corps Sediment Sampling Program

(1) General. A Corps sediment sampling program for the Muddy River was completed during the summer of 1992, to provide an update on current conditions and determine disposal requirements for any potential dredging project. Fifteen sediment samples were collected from the top 2 feet of river deposits during 23-25 June 1992 at

locations shown in plate C-7. A sediment analysis summary is shown in table 34. As well as high organic sludge deposits that have built up in the sediment, there have been accumulations of oils and metals. Arsenic is shown to range from 2.1 to 31 ppm, cadmium ranges from less than 0.65 to 12 ppm, chromium ranges from 17 to 590 ppm, copper ranges from 56 ppm to 1,000 ppm, nickel ranges from 12 to 100 ppm, lead ranges from 220 to 2,100 ppm, zinc ranges from 130 to 1,500 ppm, and mercury ranges from 0.2 to 6.4 ppm. Total petroleum hydrocarbons (TPH) ranged from 260 to 16,000 ppm. The heaviest concentration of pollutants were located generally just downstream from major storm drain outlets and in the Back Bay Fens area.

(2) Evaluation of Sediment. Two general sediment ranking systems used in the report, "Upper Mystic Lake Watershed Urban Runoff Project," dated October 1982, by the Massachusetts Department of Environmental Quality Engineering were applied to the data to determine overall river sediment quality. The ranking systems were the Great Lakes Sediment Rating Index as developed by EPA, Region V, and the Sediment Pollution Index (SPI).

The Great Lakes Index (GLI) provides interim guidelines to characterize sediment into nonpolluted, moderately, and heavily polluted categories. Criteria used for this classification are shown in table 35. In comparing GLI values with those obtained from sediment sampling, we determined that every sediment sampling point measured had at least one parameter in the heavily polluted category, with parameters of lead, copper, arsenic, zinc, and mercury showing the most consistent exceedances of the criteria. Cadmium and nickel had the least exceedance of heavily polluted criteria.

The Sediment Pollution Index (SPI) compares conditions encountered in a lake with sediment data from other areas. It uses the Clarke Number (CN), which reflects the average natural occurrence of metals in the earth's crust, thereby providing a basis for estimating the background level of metals in the sediments. A listing of the Clarke Number is shown in table 36. The index is limited as it deals with average numbers and does not take into account the variability, existing with upstream geologic conditions, sediment particle sizes, or amount of organics. The older the sediments and the more reactive the chemical environment, the higher are the leachate rates of metals from the sediments, and the higher the SPI number. A rule of thumb to be used in evaluating the pollutional content of sediment is to assume that, for a sediment to be classified as clean, the ratio of trace metal concentrations to the CN for that particular metal should be less than two. For more common metals, the ratio should rarely exceed one. Data for a site with a number of different metal results may also be analyzed to come up with a cumulative ratio. As expected, this method smooths out "outlier" ratios. In the Upper Mystic Lake Watershed report, a cumulative ratio of 10 was estimated as an index of pollution, based on sampling 15 other polluted and nonpolluted Massachusetts lakes.

When the individual Muddy River samples were averaged and compared for each metal, arsenic, cadmium, lead, and mercury had ratios exceeding the polluted index of 10.

TABLE 29
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

ALGAE COUNT AND IDENTIFICATION
(units/ml)

	24 June*				14 August**			
Station	Diatoms	Greens	Blue Greens	Total	Diatoms	Greens	Blue Greens	Total
W-5	556	121	17	694	18	34	6	57
W-11	208	325	85	618	46	76	68	190
W-13	380	286	50	716	--	--	--	--

NOTES:

1. Diatom species include Tabellaria, Cocconeis, Cyclotella, and Asterionella.

2. Green algae include Chlamydomonas, Carteria, Aktinastrum, and Cryptomonas.

3. Blue green algae include Oscillatoria and Anabaena.

4. Field observation showed large mats of blue-green algae (probably Oscilltoria).

* Dry Weather ** Wet Weather

TABLE 30
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

METALS
ARSENIC--CADMIUM--CHROMIUM
(mg/l)

	24 June*			14 August**		
Sta.	Arsenic (total)	Cadmium (total)	Chromium (total)	Arsenic (total)	Cadmium (total)	Chromium (total)
W-1	<0.0022	<0.0091	<0.012	------	------	-----
W-2	<0.0022	<0.0091	<0.012	------	------	-----
W-3	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012
W-5	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012
W-6	<0.0022	<0.0091	<0.012	0.0024	<0.0091	<0.012
W-7	------	------	-----	<0.0022	<0.0091	<0.012
W-8	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012
W-9	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012
W-10	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012
W-11	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012
W-12	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012
W-13	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012
W-14	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012
W-15	<0.0022	<0.0091	<0.012	<0.0022	<0.0091	<0.012

* Dry weather ** Wet weather

TABLE 31
MUDDY RIVER
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

METALS
COPPER--IRON--MERCURY

Station	24 June*			14 August**		
	Copper (total)	Iron (total)	Mercury (total)	Copper (total)	Iron (total)	Mercury (total)
W-1	<0.025	0.14	<0.0005	-----	----	------
W-2	<0.025	0.57	<0.0005	-----	----	------
W-3	<0.025	0.23	<0.0005	0.026	0.51	<0.0004
W-5	<0.025	0.73	<0.0005	0.069	0.65	<0.0004
W-6	<0.025	0.73	<0.0005	0.043	1.2	<0.0004
W-7	-----	----	-----	0.029	0.91	<0.0004
W-8	<0.025	0.89	<0.0005	0.030	1.3	0.0002
W-9	<0.025	0.89	<0.0005	0.033	0.98	<0.0004
W-10	<0.025	0.99	<0.0005	0.063	1.0	0.0002
W-11	<0.025	1.2	<0.0005	<0.025	1.2	<0.0004
W-12	<0.025	1.1	<0.0005	<0.025	1.1	0.0002
W-13	<0.025	1.3	<0.0005	<0.025	1.2	<0.0004
W-14	<0.025	1.7	<0.0005	<0.025	1.1	<0.0004
W-15	<0.025	1.4	<0.0005	<0.025	0.99	<0.0004

* Dry weather ** Wet weather

TABLE 32
CORPS OF ENGINEERS
1992 WATER QUALITY SAMPLING RESULTS

METALS
NICKEL--LEAD--ZINC
(mg/l)

	24 June*			14 August**		
Station	Nickel (total)	Lead (total)	Zinc (total)	Nickel (total)	Lead (total)	Zinc (total)
W-1	<0.028	<0.0066	0.11	-----	------	-----
W-2	<0.028	<0.0066	0.061	-----	------	-----
W-3	-----	<0.0066	0.12	-----	0.0033	0.092
W-5	<0.028	<0.0066	0.12	<0.028	0.014	0.11
W-6	<0.028	<0.0066	0.10	<0.028	0.015	0.075
W-7	-----	------	----	<0.028	0.0092	0.095
W-8	<0.028	<0.0066	0.11	<0.028	0.011	0.066
W-9	-----	<0.0066	0.056	-----	0.012	0.078
W-10	-----	<0.0066	0.047	-----	0.011	0.087
W-11	<0.028	<0.0066	0.046	<0.028	<0.0007	0.044
W-12	-----	<0.0066	0.048	-----	<0.0007	0.067
W-13	-----	<0.0066	0.10	-----	<0.0007	0.064
W-14	<0.028	<0.0066	0.13	<0.028	<0.0007	0.020
W-15	<0.028	<0.0066	0.15	<0.028	<0.0007	0.033

*Dry weather ** Wet weather

TABLE 33
U.S. ENVIRONMENTAL PROTECTION AGENCY
FRESHWATER CRITERIA FOR SELECTED HEAVY METALS
DESIGNATED TO PROTECT AQUATIC LIFE

Metal	24-Hour Average Limit	Maximum Limit
Arsenic	0.19 mg/l	0.36 mg/l*
Cadmium	0.0011 mg/l	0.0039 mg/l**
Chromium	0.12 mg/l	0.98 mg/l*
Copper	0.0065 mg/l	0.0092 mg/l*
Iron	------	1,000 mg/l
Mercury	0.000012 mg/l	0.0024 mg/l**
Nickel	0.056 mg/l	1.1 mg/l*
Lead	0.0032 mg/l	0.082 mg/l**
Zinc	0.047 mg/l	0.165 mg/l *

* Based on a hardness of 50 mg/l ** Based on a hardness of 100 mg/l

TABLE 34

MUDDY RIVER
CORPS OF ENGINEERS
SEDIMENT SAMPLING DATA (JUNE 1992)
(ppm)

	Sediment Sampling Location							
Parameter	1	2	3	4	5	6	7	8
Arsenic	2.1	8.2	17	19	20	19	31	23
Cadmium	<.65	4.6	1.7	1.9	5.2	1.9	1.3	2.2
Chromium	17	150	30	46	130	44	37	53
Copper	56	310	170	230	570	170	220	230
Lead	220	1400	410	730	2100	420	350	280
Mercury	0.2	1.6	0.8	1.6	3.2	0.9	0.2	0.7
Nickel	12	45	28	42	72	32	35	37
Zinc	130	630	350	460	660	290	360	450
PCB	0.59	---	0.76	---	3.6	---	0.18	----
TPH	530	16000	1400	4000	11000	1300	1200	1800

	Sediment Sampling Location						
Parameter	9	10	11	12	13	14	15
Arsenic	21	24	10	6.8	6.8	14	31
Cadmium	6.5	4.9	6.2	12	<1.3	7.1	2.8
Chromium	590	38	61	93	30	91	49
Copper	690	240	360	1000	160	340	270
Lead	1900	390	1100	1800	490	870	660
Mercury	6.4	1.4	0.5	1.6	1.4	2.0	2.2
Nickel	100	28	38	52	23	43	35
Zinc	1400	510	720	1500	390	630	770
PCB	----	1.8	2.6	----	---	---	0.26
TPH	4200	1400	4400	1500	260	2100	530

TABLE 35
GREAT LAKES SEDIMENT RATING CRITERIA
(mg/kg dry weight)

Constituent	Nonpolluted	Moderately Polluted	Heavily Polluted
Arsenic	<3	3-8	>8
Cadmium	*	*	>6
Chromium	<25	25-75	>75
Copper	<25	25-50	>50
Lead	<40	40-60	>60
Mercury	*	*	>1
Nickel	<20	20-50	>50
Zinc	<90	90-200	>200

* No lower limits defined

Source: Urban Mystic Lakes Watershed Urban Runoff Project, Massachusetts DEQE, October 1982

TABLE 36
AVERAGE ABUNDANCES OF METALS IN THE EARTH'S CRUST "CLARKE NUMBER"

Metal	Clarke Number Earth's Crust (mg/kg)	Metal	Clarke Number Earth's Crust (mg/kg)
Arsenic	1.8	Cadmium	0.1
Chromium	100	Copper	55
Lead	12.5	Mercury	0.08
Nickel	75	Zinc	70

Source: Urban Mystic Lakes Watershed Urban Runoff Project, Massachusetts DEQE, October 1982

Averaging these individual ratios drove the accumulated metals index to 19.4.

These high levels of metals in the sediments can be expected to leach out every time the DO in the water column is depleted, as a result of organic sediment biodegradation, creating a nearly constant source of pollutants during the warm summer months.

f. <u>Analysis of Current Water Quality Conditions</u>. In general, current water quality problems in the Muddy River are typical of older highly urbanized river basins in many of the larger cities of the United States. These problems include organic and suspended solids loads from point and nonpoint sources which during storm events stress the stream's natural capacity to assimilate waste; street litter, and runoff of heavy metals due to automobiles and industry result in harmful depositional problems; accidental oil spills and illegal car maintenance practices on city streets result in a significant petroleum hydrocarbon levels in the stream environment; etc.

The Muddy River's problems include oil spills, dry and wet weather domestic sewage discharges from cross connections, combined sewer overflows beginning at the lower end of Leverett Pond and continuing downstream, and water quality degradation from historical accumulation of polluted organic sediments. Perhaps the most important factor is the unique stagnant characteristic of the river's lower portion, the Back Bay Fens, which exacerbates the problems of urban runoff on the river's assimilative capacity. Due to high incoming pollutant loads, low assimilation capacity, and its unique hydraulic characteristics, the Muddy River, with the exception of Jamaica Pond, fails on frequent occasions to meet Class B standards throughout its entire length.

Water quality conditions within the Muddy River appear to have improved slightly since 1986 when the MDWPC completed their water quality survey. However, the improvement has not been sufficient to meet State water quality classification criteria, with waters still not achieving Class B standards. The most significant problem, and a human health concern, is the very high fecal coliform exceedances, generally existing the entire length below Jamaica Pond. This is followed in order by (1) low dissolved oxygen levels occurring regularly below the Route 9 bridge, (2) high nutrient levels and associated excessive algae growth problems (significant variations in pH, DO, turbidity, etc,), (3) high organic, metals, and trash releases from storm drain discharges, (4) releases of heavy metals, organic acids and gasses from bottom sludges after DO has been depleted, and (5) occasional accidental oil spills throughout the entire length.

5. WATER QUALITY IMPROVEMENT PROJECTS

a. General. Water quality improvement projects have been proposed for the Muddy River and the Charles River Basin by various interests since their first use as public sewers. The Olmsted Plan, in the late 1800s was the first known attempt to improve water quality conditions in the area. It provided for diversion of polluted upper Muddy River waters through the Muddy River conduit, and allowed the natural tidal movement to flush out the Back Bay Fens area.

The "Olmsted Park, Historic Landscape Report," by Richard Bosck, dated 1986, states that river sedimentation is the result of three factors: eutrophication (caused by shallow depth of the ponds and high organic and nutrient loading), erosion, and drain originated sediment loads. Erosion control measures have recently been adopted along Leverett Pond with placement of gabion mattresses along the shoreline. Sedimentation problems developed from storm drain discharges, particularly at the outlet to the Village Brook, Daisy Field, and Chestnut Street Drains in the late 1800s and early 1900s and dredging was completed at various locations in 1899, 1930 and 1963. Although these dredging projects were completed for flood control concerns, actual removal of the highly organic sediment provided temporary reduction in benthic demand for dissolved oxygen from sediments in the dredged area.

A majority of the more recent actions have focused on removal of Muddy River's water quality problems at the source, by reducing combined sewer overflows and elimination of sewer cross connections. Ongoing studies and corrective action since the early 1970s have identified and eliminated a number of pollutant sources, resulting in an improvement in water quality conditions recently.

b. Proposed Water Quality Recommendations by Others

(1) General. The elimination of sewage pollutants at the source has only recently been given priority (within the last 20 years). Numerous recent combined sewer separation projects undertaken by the communities of Boston and Brookline have resulted in substantial reduction of sewage into the Muddy River. Brookline has a lesser number of combined sewer areas, so their effort has most recently been placed in elimination of illegal cross connections in the Tannery Brook drainage system. A recent study by Camp Dresser & McKee in 1989, identified approximately 54 illegal connections in the Tannery Brook Drain. Brookline has taken action and removed a number of these connections; however, based on results of recent water quality testing, it appears a large number of connections still exist. The city of Boston has also been involved repairing combined sewer regulators, and removing cross connected sewer connections from the storm drain system at the Daisy Field Drain.

Some more comprehensive studies that have attempted to provide water quality improvement in the Muddy River include the following:

(2) <u>Flow Augmentation of the Boston Back Bay Fens Pond</u>. This study, prepared in February 1977 by CE Maquire, Inc. for MDWPC, was completed to identify ways to augment flow in the Back Bay Fens for the purpose of eliminating its stagnant condition, and making it habitable for fish and wildlife propagation. One basic premise in this report was that a proposed combined sewer overflow detention (CSO) facility (Charles River CSO Facility) would be constructed. This facility would allow storage of Stony Brook Conduits' first flush, followed by release to the Deer Island Treatment Plant after the storm. In addition, all flows that could not be stored would be chlorinated before release to the Fens. Flow augmentation schemes evaluated include an oxygen supply system within the Fens (bubbler system) to aerate waters to solve the dissolved oxygen problem. Flow augmentation schemes considered are:

(a) <u>City Water Supply</u>. This plan called for using drinking water to augment the river's natural flow. This scheme was not pursued since flow augmentation is needed most when oxygen is low during summer months, which is the same time the city's water supply and pressure is already limited.

(b) <u>Divert Muddy River Through the Fens</u>. This scheme would divert the Muddy River flow away from the Muddy River Conduit by sending it through the Fens. This was not pursued to any great extent since when most flow is needed (during summer months), the flow rate from the river is very low (as little as 1 cfs).

(c) <u>Circulate Charles River Through the Fens</u>. A portion of Charles River flow would be circulated through the Fens. Two of the options considered with this alternative are discussed below.

<u>1. Discharge Water Through Boston Gate Houses</u>. Water would be drawn from the Charles River, passed through the lower Back Bay Fens, and then released to Boston Marginal Conduit where it would travel to the new combined sewer overflow facility. From there, it would be pumped to the Deer Island Treatment Plant. This solution was not recommended since it entails increasing the capital costs of the proposed Charles River CSO facility, plus increasing the operating costs of the Deer Island Treatment Facility.

<u>2. Discharge Water Through Muddy River Conduit</u>. This alternative was recommended, however, not implemented. Flow would be pumped out of the Fens by a pumping station located near the Brookline Avenue Gatehouse, and then discharged to the Muddy River Conduit; thereby reversing flow in the Back Bay Fens and drawing in Charles River water. The pumps would be shut off during storm events and the flow would revert to normal by continuing through the Back Bay Fens.

(3) <u>Charles River Basin Combined Sewer Report</u>. Recommendations of the 1980 M&E report, "Combined Sewer Overflow, Charles River Basin Facilities Planning Area," which should result in beneficial water quality impacts for Muddy River drainage area are

listed below. The status of each project according to the 1990 M&E "Muddy River Water Quality Improvement Plan," is also included.

(a) Eliminate CSOs. Closure of the Kent Square and Brook Street combined sewer overflows (both reportedly have been accomplished by Brookline).

(b) Insystem Modifications. Insystem modifications to sanitary and combined sewer systems, surrounding Boston Gate Houses Nos. 1 and 2, would result in less hydraulic surcharge in the area and reduction in times that dry and wet weather sanitary flows into the Fens can occur (current estimated number of overflow events is approximately 2 to 3 times a month). Some improvements have been completed (diverting dry weather base flow from Old Stony Brook Conduit to Boston Main Drain Relief Sewer); others are planned or in progress (removal of 25,000 cubic yards of grit and sludge, elimination of illegal sewer cross connections into the Stony Brook Conduit, modifyng regulators and cleaning dry weather sewer connections to eliminate dry weather overflows to Stony Brook Conduit at Huntington Avenue--Forsyth Street, Whittier Street--Tremont Street, and Ritchie Street--Columbus Avenue.

Other recommendations, not currently being implemented by MWRA, include demolition of Boston Gatehouse No. 2 and construction of a screening and grit removal facility at Boston Gatehouse No. 1. The most recent formulated plan to reduce Boston gatehouse overflows from the Stony Brook combined systems to the Back Bay Fens calls for construction of a series of deep and near surface tunnels along with insystem capacity modifications. The proposal would eliminate overflows up to a 3-month design storm.

(c) Divert Stony Brook. The diversion of Stony Brook to the Muddy River for low flow augmentation purposes would allow Stony Brook conduit to remain empty for insystem storage of CSO. Sanitary sewer connections in the upper Stony Brook drain were proposed for elimination prior to the diversion. Construction would include a pumping station (10 mgd average, 20 mgd peak flow) and its associated force main near Green Street in Jamaica Plain. The proposed discharge was to Ward's Pond. Jamaica Pond was not selected because pumping costs would be higher (more head), and opposition from local community organizations was likely. Modifications would be needed to the open channel between Ward's and Willow Ponds to enable the increased flow to pass. According to M&E, the MWRA has recommended this project not proceed.

(d) Modify Flow and Flow Areas. Direct modification of flows and flow areas within the Back Bay Fens area including:

1. Modify Gatehouse. Modification of the existing Brookline Avenue Gatehouse to allow the Muddy River to discharge to the Fens, rather than to the Muddy River Conduit. Flow would be routed through the conduit only during major storms when hydraulic capacity of the Fens is reached. Low flows of the Muddy River can be quite small,

making this option less attractive.

2. Construct Control Structure. Construction of the Muddy River Screening and Flow Control Facility at the inlet of Muddy River to the Fens, in order to remove floating material and provide hydraulic control of flow entering the Fens.

3. Dredge Sediments. Dredging and degritting approximately 150,000 cubic yards of sediment deposits accumulated in the Fens. Grit would be trucked to MWRA's Deer Island Treatment Plant. Degritted sediment would be discharged to the MWRA sewer system for treatment at the Deer Island Plant. In a later document by Camp, Dresser & McKee, "Environmental Impact Report for the Control of Combined Sewer Overflows for Neponset River, Dorchester Bay, Charles River Basin, Boston Inner Harbor," dated February 1982, the recommended dredging scheme was modified. Dredging was limited to a 3-foot depth for part of the channel since that likely would be as effective as the full dredging proposal. Cost would be lower (only 20,000 cubic yards to be dredged), and there could be greater benefit to the dissolved oxygen balance. It was felt that dredging to a deeper depth could result in anoxic conditions in the bottom of the Fens ponds. This could be a drawback since high BOD loadings from storm drains and sewers would still occur even after organic sediments were removed.

According to M&E's 1990 Muddy River Water Quality Improvement Plan report, the District Court of Massachusetts ordered the MWRA to delete all these projects after the MWRA presented testimony indicating they would not reduce CSO discharges, are too expensive, and may conflict with preliminary proposed work under the Olmsted "Emerald Necklace" restoration program.

(4) Muddy River Water Quality Plan. M&E in their "Muddy River Water Quality Improvement Plan," dated September 1990, recommended a number of projects which would cause water quality improvements in the Muddy River. Among these are the following:

(a) Upper Muddy River Area

1. Remove Cross Connections. Investigate and continue removing sewage discharges from the Daisy Field, Tannery Brook, Village Brook, and Longwood Avenue drainage systems.

2. Eliminate Sewer Siphon Overflow. Investigate reason for Francis Street sewer siphon overflow problem, and if surcharging source cannot be readily corrected, construct a larger siphon (approximately 24-inch pipe) under the river.

3. Construct Gross Particle Separators. Gross Particle Separators are treatment structures used for removing floatable waste and sediment from urban stormwater runoff. Each separator consists of a segmented tank with baffle walls, which hinder

passage of floatables and sediment before releasing flow on the opposite end of the tank. Boston has constructed a demonstration separator on the Fenwood Drain subarea. M&E has called for construction of approximately 110 gross particle separators at the downstream end of storm drainage subsystems to reduce primarily solids and oil from the Muddy River. The exact location of these units has not been determined. They would require timely operation and maintenance procedures to ensure proper operation.

4. Dredge Sediments. Dredge approximately 90,000 cubic yards of organic sediment from the Muddy River in the area above the Back Bay Fens. Dredging was proposed primarily to reduce the significant benthic demand for dissolved oxygen, although some flood control benefits were included. It was proposed that the dredged materials be mechanically dewatered and disposed of most probably at an out-of-State landfill or through ocean disposal.

5. Phragmites Removal. Removal of phragmites in those areas generally downstream from Route 9 where sediments have accumulated. Harvesting these plants removes nutrients from the system.

(b) Back Bay Fens

1. Reduce Combined Sewer Overflows. Reduce dry and wet weather overflow from Boston gatehouses into the Fens. Current MWRA plans call for reduction of all dry weather flows and elimination of all wet weather overflow events greater than a 3-month storm.

2. Redirect Muddy River Flow into Fens. Modify the Brookline Avenue Gatehouse to direct Muddy River dry weather flows into the Back Bay Fens, and use the existing Muddy River Conduit as an overflow during rainfall-runoff events. This would increase the normal base flow into the Fens to approximately 12 cfs.

3. Dredge Sediments. Remove, dewater, and dispose of approximately 150,000 cubic yards of sediment from the Back Bay Fens. In addition, another 1,500 cubic yards should be removed from twin 72-inch culverts connecting the Muddy River to the Fens. Final removal of dredged material would be to an out-of-State landfill or ocean disposal.

4. Remove Phragmites. Removal of phragmites in the area surrounding the Fens to promote nutrient reduction.

(c) System Wide Improvements

1. Divert Stony Brook to Muddy River. Low flow augmentation from upper Stony Brook above Green Street to the Muddy River should be implemented. Construction would include a 10 mgd pumping station and its associated force main, which

would be connected to Ward's Pond. The 20 mgd peak flow from a previous study to provide extra CSO storage capacity in the Stony Brook Conduit was not adopted. This extra capacity is not needed because MWRA's proposed deep tunnel plan will handle wet weather flows from the Stony Brook Conduit.

2. Develop Water Quality Monitoring Program. Institution of a water quality sampling and analysis program to monitor progress of cleanup programs and identification of pollutant sources must be accomplished.

3. Best Management Practices. Institution of watershed best management practices, which will result in some improvements to water quality. These practices include street sweeping programs; fertilizer, pesticide, and underground storage control; catch basin cleaning; park land maintenance and cleanup of large debris.

(5) Muddy River Instream Treatment Demonstration Preproposal. A proposal for a demonstration project to treat Muddy River water is currently being developed by two professors from Northeastern University in Boston, MA, and a former official of the MDWPC. Although in its early stages, the plan consists of pumping water (approximately 500 gpm) from the lower Muddy River before it reaches the Back Bay Fens, providing some form of biological secondary treatment to the water (trickling filter and/or rotating biological discs), and then releasing the water through an aeration device (cascade or fountain) to increase DO in the stressed lower Muddy River. The discharge point is estimated to be at the same point on the Muddy River from where the water was withdrawn. The concept is to remove as much dissolved organic pollutants as possible, and aerate the water as much as possible. Efforts are being made by proponents to obtain funding from EPA as a demonstration project.

At the present time, there have been very few, if any, similar treatment facilities constructed to treat stream waters. The city of Chicago, IL, however, is in the process of constructing five different cascade type facilities to aerate water of the highly polluted Calumet Waterway. Engineers associated with this much larger project estimated the cascade system will be less than one-seventh the cost of a conventional wastewater treatment system. For the Chicago project, it was also determined that aeration would only be required in warm weather. As a result, the standard instream air blower system was not chosen since it tends to clog, unless blowers operate year-round. Also, offstream deployment of the cascade system (directly adjacent to the waterway) eases operation and maintenance problems, leaving the channel free for recreational and commercial water traffic.

c. <u>Evaluation of Measures to Improve Water Quality</u>

(1) <u>Proposed Corps Flood Control Alternatives</u>

(a) <u>General</u>. In addition to those proposals based on water quality considerations alone, the Corps of Engineers as part of this reconnaissance study, has also developed two flood control alternatives (a Comprehensive and a Minimimum Plan), which may aid in water quality improvement. In the following paragraphs, flood control alternatives will be evaluated, based on water quality considerations.

(b) <u>Comprehensive Plan</u>

<u>1. General</u>. The water quality impacts of two options evaluated under the comprehensive plan alternative are described below.

<u>2. Option A</u>. This scheme consists of:

a) Replacing the twin 6-foot culverts upstream from the Brookline Avenue Gatehouse with a 10 by 20-foot box culvert 535 feet long.

b) Dredging the Muddy River in the Back Bay Fens area from the outlet of the culverts under Brookline Avenue to the Boylston Street bridge. The channel would be dredged to -4.0 NGVD, have a bottom width of 30 feet, and side slopes no steeper than 1 on 2.

c) Replacing the twin 6-foot culverts at Louis Pasteur Avenue with an open channel. This channel would be excavated to -4.0 NGVD, have a bottom width of 30 feet, and side slopes no steeper than 1 on 2.

Added flow would be sent to the Fens instead of going down the Muddy River Conduit. This change will result in improved flushing characteristics within the Fens during storm events; however, additional organic sediments may be transported to the Fens. During nonstorm status, stagnant conditions with little flushing capability will continue to be a problem.

Less sedimentation and greater scouring of fine organic materials will take place upstream in the Muddy River where there will be a slight increase in hydraulic gradient. Increased flushing of upstream sediments during storms may result in increased sedimentation within the Fens area. Even though some added sediment may be transported into the Charles River Basin from the Fens, it is likely that net sediment deposition in the Fens will increase due to its large channel area, sluggish velocity and low hydraulic gradient. This plan will help in decreasing benthic demand of organic sediments in the upstream

Muddy River, but the Back Bay Fens area may suffer. Making a portion of the culvert open channel (near Louis Pasteur Avenue) will provide more surface area for re-introduction of dissolved oxygen. It would be extremely hard to measure minor water quality improvements associated with these culvert changes.

There will be temporary harmful effects during dredging as sediments are stirred up by the mechanical process and heavy metals, suspended solids, and organic compounds are released to the water column. Precautions will be taken to minimize the effects through improved dredging techniques.

Dredging and proper disposal of these highly contaminated sediments will be beneficial to water quality, since currently the Muddy River and Back Bay Fens are acting as a primary settling tank for sewage sludge and organic and inorganic storm drainage pollutants. Anaerobic biodegradation in these settled sludge areas of the Muddy River and Fens, although being one of nature's organic cleaning processes, is extremely slow in comparison to what would occur in an aerobic condition. As a result, harmful metal releases and low dissolved oxygen levels linger, making the water column unhealthy for a longer period of time. There will be a short term beneficial impact to water quality after dredging is completed, due to reduced benthic demand. However, with time and no source control, dry weather sewage flows, wet weather combined sewer overflows, and wet weather storm drainage flows will all settle out once again in the same dredged areas. High organic and metal sludges from these pollutant sources will again result in a high benthic demand throughout the area.

3. Option B. This scheme would be the same as Option A except the culvert under the Sears parking lot (about 335 feet in length) would be replaced with a channel having a bottom width of 20 feet and 2 on 1 side slopes.

This alternative has similar water quality effects to the alternative described above, except that a change to open channel conditions for a portion of this reach will provide more surface area for reintroduction of dissolved oxygen during various flow conditions. Any minor water quality improvement will be hard to measure.

(c) Minimum Plan. This plan would only involve replacing the twin 6-foot culverts upstream from the Brookline Avenue Gatehouse. There would be no dredging involved and the twin 6-foot diameter culverts located at Louis Pasteur Avenue would not be modified. As with the previous Comprehensive alternative, two options would be considered under this plan; a) using a 10 by 15-foot box culvert, 535 feet long, and b) using a 10 by 15-foot box culvert, 200 feet long under Park Drive with 335 feet of open trapezoidal channel in the Sears parking lot.

This alternative would produce a less steep hydraulic gradient than the Comprehensive alternative since there will still be a minor constriction at Louis Pasteur Avenue. The result will be less scouring of organic sediment in the upstream Muddy River, and lesser movement of sediments into the Fens area than the Comprehensive Plan alternative. Again, water quality changes relative to culvert modifications, would be hard to measure. There will be no beneficial impacts related to dredging since none is proposed in this Minimum Plan.

(2) <u>Recommended Measures to Improve Water Quality & the Riverine Habitat</u>

(a) <u>General</u>. The following discussion focuses on various measures which can be implemented by State and local agencies to improve water quality and the riverine habitat within the basin. The Corps of Engineers does not presently have authority to participate in improvements for water quality alone. Other plans have previously been presented from existing reports and are worth pursuing; however, these alternatives are the easiest to implement and will have a significant impact.

(b) <u>Source Control</u>. Theoretically, the ideal method to improve water quality in the Muddy River Basin is to eliminate pollutants at their source. However, implementation of source control projects for an older urban watershed is extremely difficult due to the high cost.

The highest priority source control projects that provide the greatest opportunity for water quality improvement within the Muddy River are elimination of sewer cross connections from the Daisy Field, Tannery Brook, Village Brook, and Longwood Avenue drainage systems so there are no dry weather flow sewage discharges to the river. These discharges have resulted in nearly continuous violation of fecal coliform criteria in the Class B standards from the lower end of Leverett Pond downstream through the Back Bay Fens.

The next priority, and perhaps the hardest to implement, is the continuance of best management practices. The impact of storm drain discharges is not as dramatic over the short term as it is over time. Long term effects result in oxygen depletion, algae bloom conditions, and accumulation of toxic metals and oils in the ecosystem of the Muddy River. The communities of Boston and Brookline should continue providing best management practices in the basin including: routine street sweeping, storm drain and sewer maintenance, catch basin cleaning; reduced road salting for deicing; reduced fertilizer application for parkland, and erosion control measures to promote improved river water quality. In addition, as discussed in the 1990 M&E report, there should be a public education program developed to reduce littering, and the park area should be posted, noting fines for littering and illegal automobile maintenance. Underground oil tank leaks should also be reduced through a process of registering oil tanks and testing them for tightness. This will result in reduction of organics, oils, fertilizers, and metals from storm drain discharges.

Other projects which are recommended, but over the long term due to their higher costs and implementabilities, are elimination of overflows from the combined sewer system, currently released through Boston Gatehouse Nos. 1 and 2, and elimination of surcharging from the St. Francis Street sewer siphon. Discharge from these sources are much less frequent; however, their impact is much more dramatic and long lasting as a result of the large amounts of organic sludge which can be released during a storm event. Long after the effects of high bacterial releases have subsided, the sludge will continue depleting the oxygen from the water column.

Construction of Gross Particle Separators described in M&E's report will provide another form of source control (if constructed in the upper drainage area) which will help in reducing the amount of pollutants reaching the Muddy River. However, they require a significant amount of maintenance to work properly and an adequate labor force is needed to make sure that sediments and floatables are removed periodically. As a result, construction of a significant number of these separators is not recommended until specific maintenance requirements are identified. Data should be collected from the demonstration separator that was installed by the city of Boston in the Fenwood drainage subarea, to determine maintenance needs and determine how efficient its operation is prior to further implementation.

(c) Instream Treatment/Dissolved Oxygen Addition. Depending on how elaborate the treatment/DO scheme, this program could be the least costly and one of the easiest to implement. The impacts will be immediate, treating the symptoms of a highly polluted stream by accelerating nature's self-cleansing properties. The capital expense items could be relatively low if the constructed project is temporary, intended to serve only until more long term projects are completed (source control, dredging following source control, and flow augmentation). The operation of a treatment facility or dissolved oxygen bubbler system could be intermittent (only during the summer months), keeping operation costs to a minimum. This type of scheme could become more permanent if sufficient study reveals the process cheaper than maintaining a source control program for storm drain discharges or implementing flow augmentation.

(d) Flow Augmentation. Flow augmentation for low flow periods appears to be a long term requirement of maintaining a healthy riverine environment within the Muddy River. In an urban area such as the Muddy River Basin, it is not expected that source control through best management practices alone will completely eliminate all pollutants entering the river. As a result, flow augmentation will be needed to provide sufficient velocities to deter sedimentation, and provide sufficient volume of flowing water to maintain a high dissolved oxygen content for assimilating pollutant demand.

The simplest flow augmentation schemes to implement is diversion of more Muddy River water to the Fens at the Brookline Avenue Gatehouse through repairs or modifications, release of city of Boston water supply at the upstream end of the Muddy River, and discharge of water from a groundwater well to the upstream end of the Muddy River. Identification of water quality impacts from these alternatives are difficult. Diversion of the Muddy River to the Fens during storm events may help scour out sediments from the Fens to the Charles River Basin. However, it could also increase sedimentation in the Fens, as water generally passed to the Muddy River conduit will now flow through the Fens depositing its suspended solids load. When low DO is a problem in the summer months, flow rate in the Muddy River is low (approximately 1 cfs). Use of groundwater well or municipal water supply release for low flow augmentation will also supply a minimal discharge (estimated at 1 to 2 cfs); however, if it can be maintained in the summer, DO conditions will benefit, if only slightly.

A number of flow augmentation schemes have been previously proposed, but are not recommended without additional study. These include diversion of upper Stony Brook into the Ward's Pond area of Muddy River, and reversal of flow from the Charles River into the Back Bay Fens area by installing a pump near the Muddy River Conduit, and pumping flow to the Muddy River Conduit during dry weather conditions. The diversion of Stony Brook would have a significant impact on Muddy River discharge due to its higher flow rate, but as yet the city of Boston has been unable to clean up all sewage connections into the brook. The alternative showing promise is reversal of the Back Bay Fens flow direction by drawing the Charles River through the Fens, and discharging flow through the Muddy River Conduit. Further study is needed to ensure that pumping to the conduit would not create additional problems in Boston's drainage system, and that reversing flow at the Charles River/Fens confluence wouldn't reentrain sediments.

(e) **Dredging.** Dredging of contaminated organic sediments, perhaps the most popular alternative, will provide dramatic short term improvement in water quality as the source of high benthic oxygen demand is eliminated. However, sediment will again build-up without progress of eliminating the pollutants at their source. Without this step, water quality characteristics of the Muddy River will soon revert to the predredged conditions. Due to the high cost associated with disposing of the contaminated sediments, we recommend that this alternative, solely for water quality improvement, not be initiated until source control has proceeded as far as possible.

(f) **Selective Removal of Phragmites.** This alternative includes removal of phragmites in riverbank areas to improve riverine habitat and restore scenic vistas. Phragmites removal will have both positive and negative impacts to water quality, depending on how accomplished. While growing, plants make use of nutrients that discharge from numerous outlets into the waterway. They also trap organic sediments and oils which pass through their stands during high riverine stages. However, when they die, and the plant is left to decompose, the nutrients once assimilated are released again to the water column. Harvesting these stands, if accomplished while the vegetation is still alive and with proper disposal outside of the watershed, will result in removal of nutrients and an overall benefit to the Muddy River watershed. Complete removal and uprooting of these stands, although beneficial to park aesthetics, will result in reducing one of nature's cleaning processes, which trap oils and sediments in the banks along the river and also helps to draw nutrients from the water.

6. SUMMARY

Following is a summary of reconnaissance study findings, developed after review of existing water quality reports for the basin, and based on sediment and water quality analysis performed by the Corps of Engineers.

a. <u>Problem Identification</u>. The Muddy River, a minor 7.5 square mile tributary of the Charles River, is located within the communities of Boston, Brookline, and Newton. It is made up a series of small ponds, interconnected by short stretches of covered and uncovered river channels.

In general, current water quality problems in the Muddy River are similar to those of many older highly urbanized river basins found in some of the larger cities of the United States. The river, although currently classified as Class B according to MA DWPC, fails to meet these criteria generally throughout its entire length, as a result of high incoming pollutant loads, low assimilative capacity, and unique sluggish hydraulic characteristics of the Back Bay Fens.

Pollutant sources to the Muddy River include: sewer cross connections from several of its major catchment areas, combined sewer overflows, periodically overflowing sewer siphon, an historically leaking skating rink refrigeration system, accidental oil spills, and urban storm drainage discharges.

A Corps of Engineers water quality sampling program was performed during dry and wet weather periods during the 1992 summer, to provide an update on conditions. In addition, a sediment sampling program was also undertaken to determine disposal requirements for any proposed dredging project and to allow definition of sediment/water quality factors.

The most significant problems identified in the investi- gation included very high fecal coliform exceedances, generally existing the entire length below Jamaica Pond, and followed in order by: (a) low dissolved oxygen levels which occur regularly below the Route 9 bridge, (b) high nutrient levels and associated excessive algae growth problems (significant variations in pH, DO, turbidity, etc.), (c) high organic, metals, and trash releases from storm drain discharges, (d) releases of heavy metals, organic acids and gasses from bottom sludges after DO has been depleted, and (e) occasional accidental oil spills throughout the entire stream length.

As part of the highly organic sludge deposits that have built up just downstream from major storm drain outlets and in the quiescent Back Bay Fens area, there are accumulations of oils and metals. After comparison to freshwater sediment criteria, we estimated that each sediment sample collected had a sufficient concentration of at least one heavy metal to be considered in the heavily polluted category. The most consistent metal problems were lead, copper, arsenic, zinc, and mercury. These concentrated metals are expected to leach out of sediments into the water column every time the DO is depleted, as a result of biodegradation; creating a constant source of pollutants during the warm summer months.

b. <u>Flood Control Improvements</u>. The Corps of Engineers as part of this reconnaissance study has developed two flood control alternatives which may also aid in water quality improvement. The alternatives considered for flood control include:

(1) <u>Comprehensive Plan</u>. The comprehensive plan con- sists of two options. Option A calls for increasing the flow area 3.5 times greater than the existing twin 6-foot diameter culverts upstream from the Brookline Avenue Gatehouse, and replacing the twin 6-foot diameter culverts located near Louis Pasteur Avenue with an open trapezoidal-shaped channel. The culvert modifications will result in altered sedimentation patterns, somewhat higher dissolved oxygen levels, and slightly greater flushing capability within the Fens.

Dredging will also be carried out in the area from the outlet of the culverts under Brookline Avenue to the Boylston Street bridge. There will be temporary harmful effects during dredging as some contaminated sediments are released into the water column. However, dredging should reduce the benthic oxygen demand over the short term. Unless an effective source control program is implemented, continual release of pollutants from cross connected sewers, combined sewer overflows, and storm drains will soon result in the same built up sludge problem that now exists.

Option B of the comprehensive plan calls for the same components as option A, except the portion under the Sears parking lot will be replaced with an open trapezoidal-shaped channel. This option has similar water quality improvements to option A, except a greater surface area will be available for reoxygenation.

(2) <u>Minimum Plan</u>. The minimum plan alternative also has two options. Option A calls for increasing the flow area 2.6 times greater than the existing twin 6-foot diameter culverts upstream of the Brookline Avenue Gatehouse. No dredging or further culvert modification would take place. The change will result in slightly reduced water quality improvements from option A of the Comprehensive Plan because a minor flow constriction will exist near Louis Pasteur Avenue. There will be no beneficial dredging benefits included in this alternative. Option B is the same as option A for the minimum plan alternative, except the proposed culvert under the Sears parking lot will be replaced with an open trapezoidal channel. This option will slightly increase the reoxygenation capability of the stream over that of option A of the minimum plan.

c. <u>Water Quality Recommendations</u>. Water quality improvement projects have been proposed by others for the Muddy River and the Charles River Basin since first used as public sewers. The Olmsted Plan in the late 1800s, providing for tidal flushing of the Back Bay Fens, was the first attempt to improve water quality conditions in the area. Since the Corps has no authority to implement improvements for water quality improvement alone, the following recommendations are provided to State and local agencies for consideration in their efforts of Muddy River cleanup.

Although no one procedure will solve all water quality problems in the Muddy River, the following major categories in various combinations can be expected to significantly improve the river's water quality and riverine habitat: source control, instream treatment/dissolved oxygen addition, flow augmentation, dredging and selective removal of phragmites.

(1) <u>Source Control</u>. The highest priority source control projects, providing the most opportunity for Muddy River water quality improvement are elimination of sewer cross connections from the Daisy Field, Tannery Brook, Village Brook, and Longwood Avenue drainage systems so that there are no dry weather sewage discharges to the river. In addition, Brookline and Boston should implement or maintain best management practices to reduce storm drain pollutants. Other possible alternatives, not recommended by the Corps at the present time because of difficulty in implementation or more information and study are needed, include: CSO elimination, sewer siphon improvement, and a system of gross particular separators. Further investigation and significant financial commitment may make these latter options viable in the future.

(2) <u>Instream Treatment/Dissolved Oxygen Addition</u>. Depending on how elaborate the treatment/DO scheme, this program may be the least costly and one of the easiest to implement. Water quality impacts will be immediate since the system will treat the symptoms of a highly polluted stream by accelerating nature's self-cleansing properties. A demonstration project to provide instream treatment is currently proposed by a local university.

(3) <u>Flow Augmentation</u>. Flow augmentation appears to be a long term requirement for maintaining a healthy riverine environment within the Muddy River, since it will deter sedimentation and help maintain the river's assimilation capacity. A number of alternatives have already been presented in previous reports by consultants, which included both the entire length of the river and lower Back Bay Fens. The ones recommended by the Corps for consideration at the present time, due to their ease of implementation are: modification of the Brookline Avenue gatehouse to allow more riverflow to pass away from the Muddy River conduit and through the Back Bay Fens area, and release of municipal or well water to the upper Muddy River. Certainly, source control improvements must accompany this alternative.

(4) <u>Dredging the River to Improve Water Quality</u>. Dredging sediments, perhaps the most popular alternative, will provide dramatic short term improvement as the source of high benthic oxygen demand is curtailed. However, sediment will again build up to predredged conditions without progress being made to eliminate pollutants at their source.

(5) <u>Selective Removal of Phragmites</u>. This alternative is recommended to improve riverine habitat and restore scenic vistas. Care must be used to optimize plant nutrient uptake and removal from the system.

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p. Analytical Data Report, Muddy River - Dry, by NED Environmental Laboratory, 22 September 1992.

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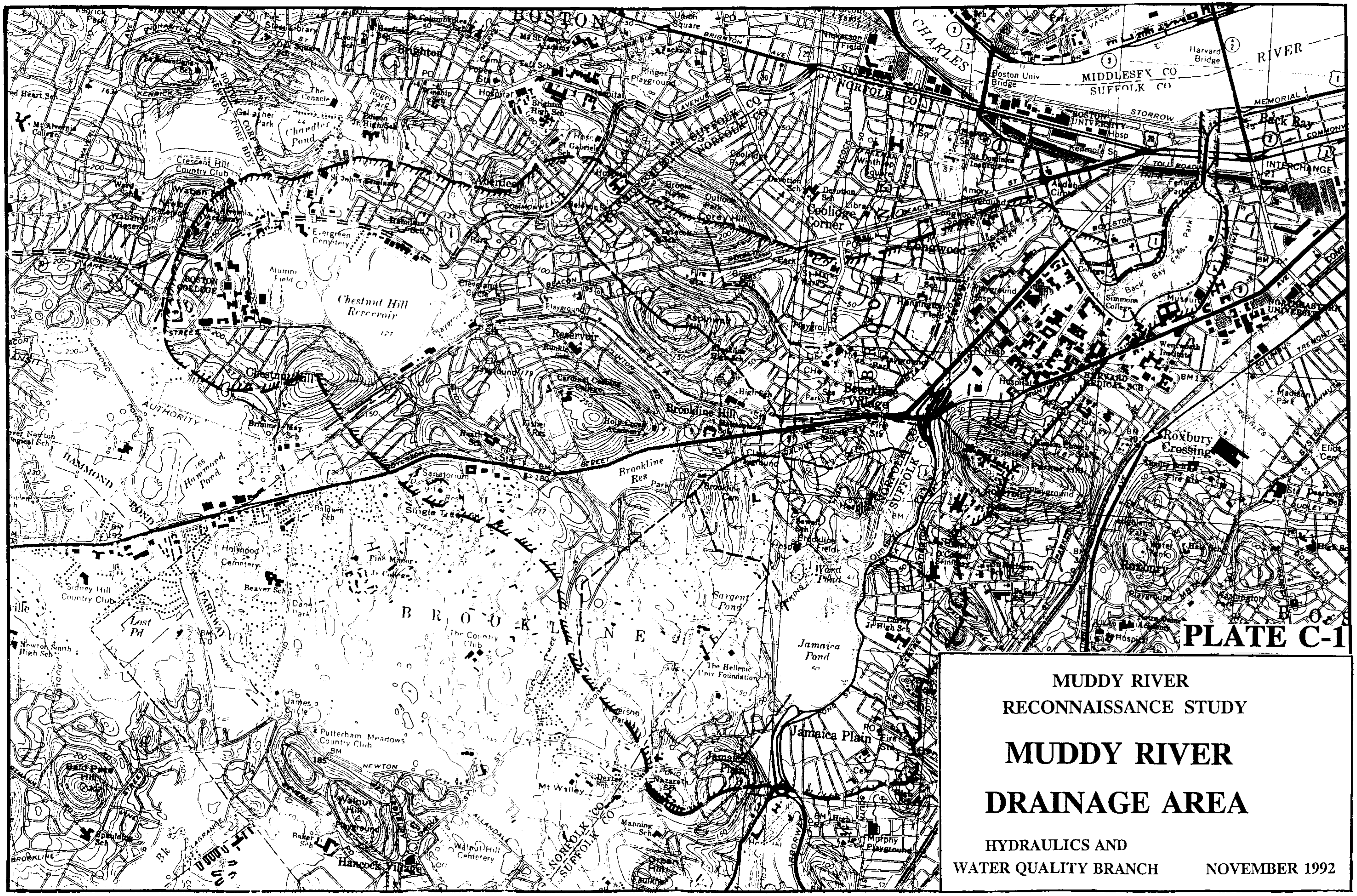


PLATE C-1

MUDDY RIVER
RECONNAISSANCE STUDY

MUDDY RIVER
DRAINAGE AREA

HYDRAULICS AND
WATER QUALITY BRANCH

NOVEMBER 1992

CORPS OF ENGINEERS

U. S. ARMY

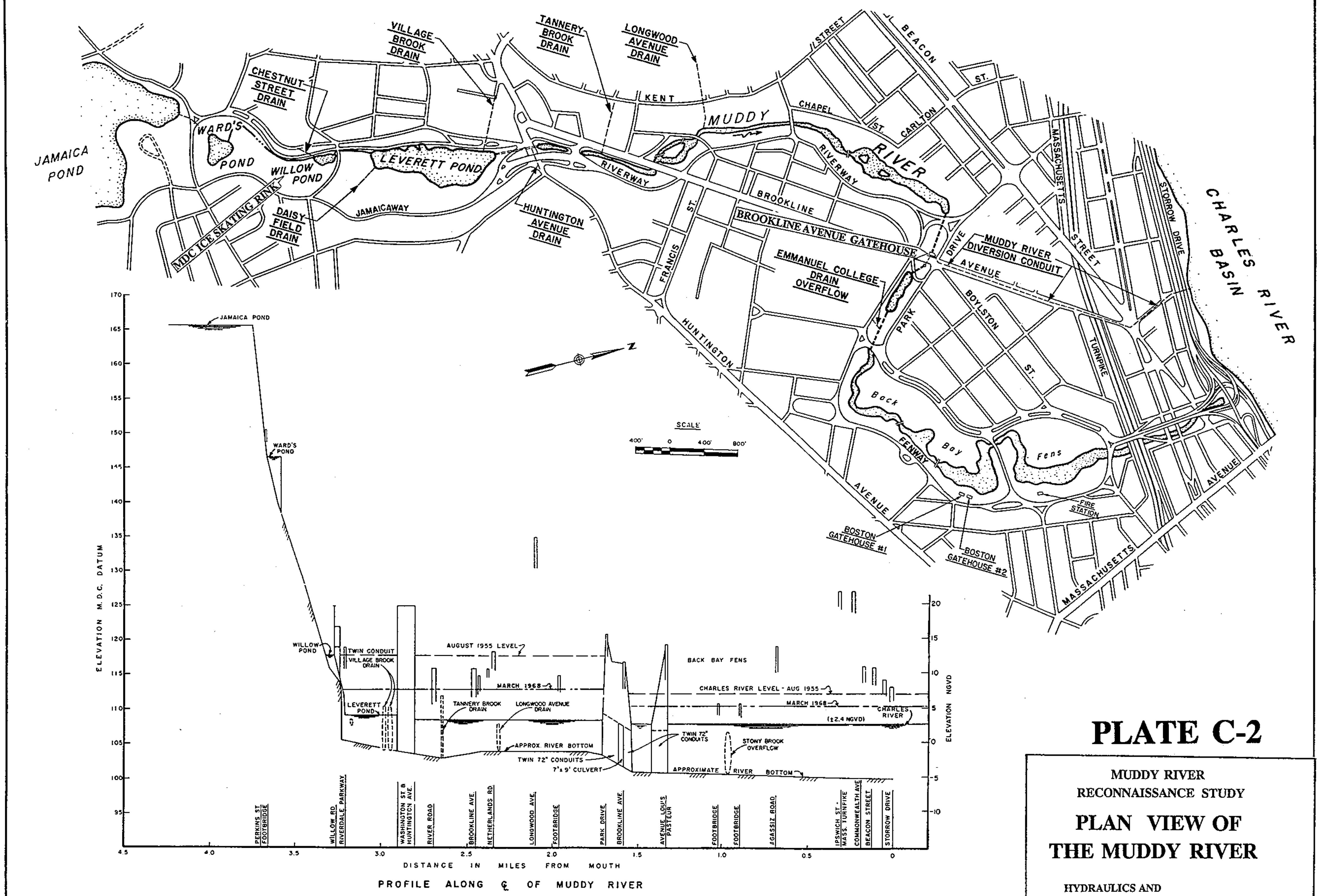


PLATE C-2

MUDDY RIVER
RECONNAISSANCE STUDY

PLAN VIEW OF THE MUDDY RIVER

HYDRAULICS AND
WATER QUALITY BRANCH

NOVEMBER 1992

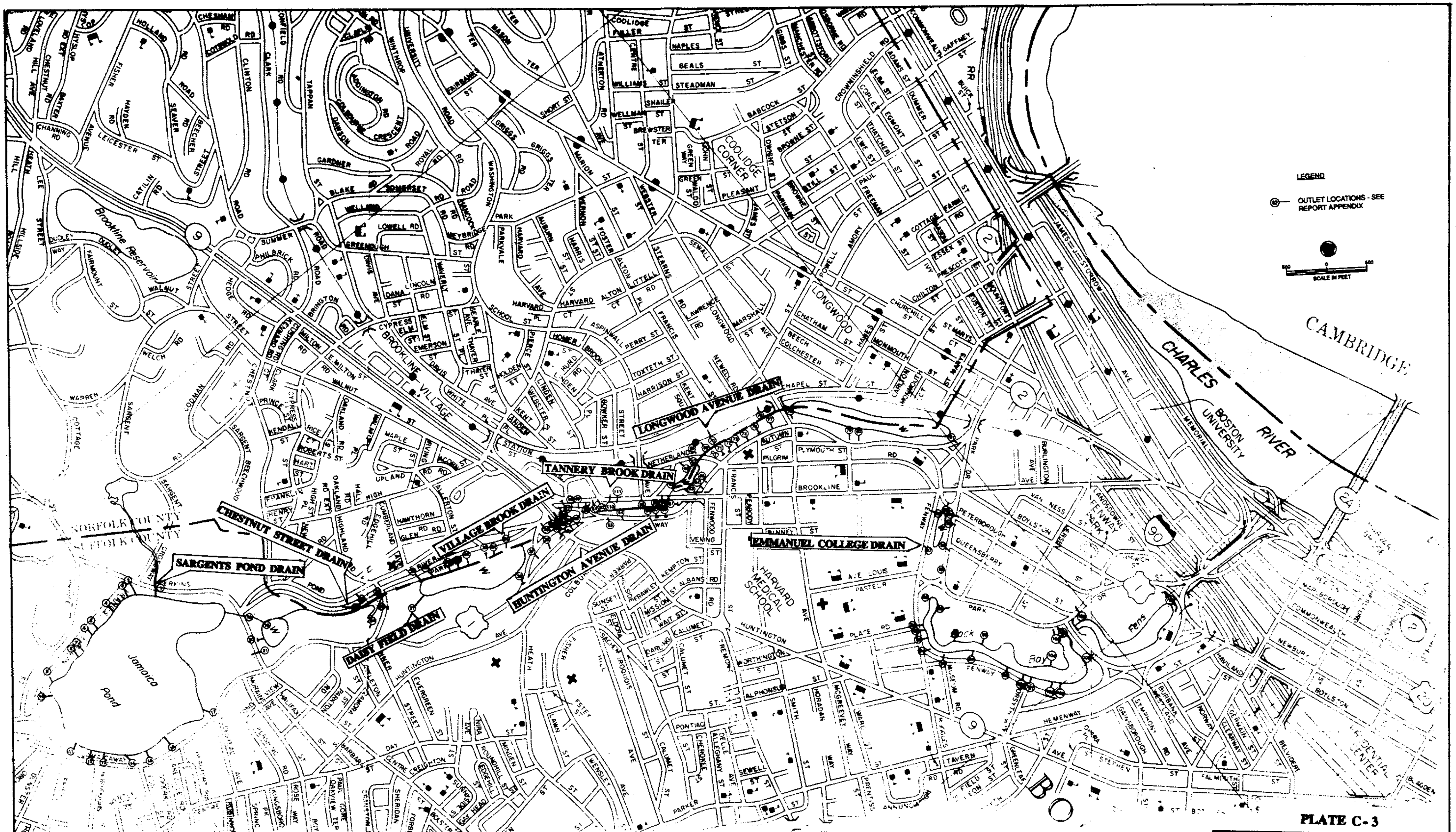


PLATE C-3

MUDDY RIVER
RECONNAISSANCE STUDY

OUTLET LOCATIONS TO
THE MUDDY RIVER

TAKEN FROM "MUDDY RIVER WATER QUALITY IMPROVEMENT PLAN", DATED 1980 BY METCALF & EDDY

HYDRAULICS AND
WATER QUALITY BRANCH

NOVEMBER 1992

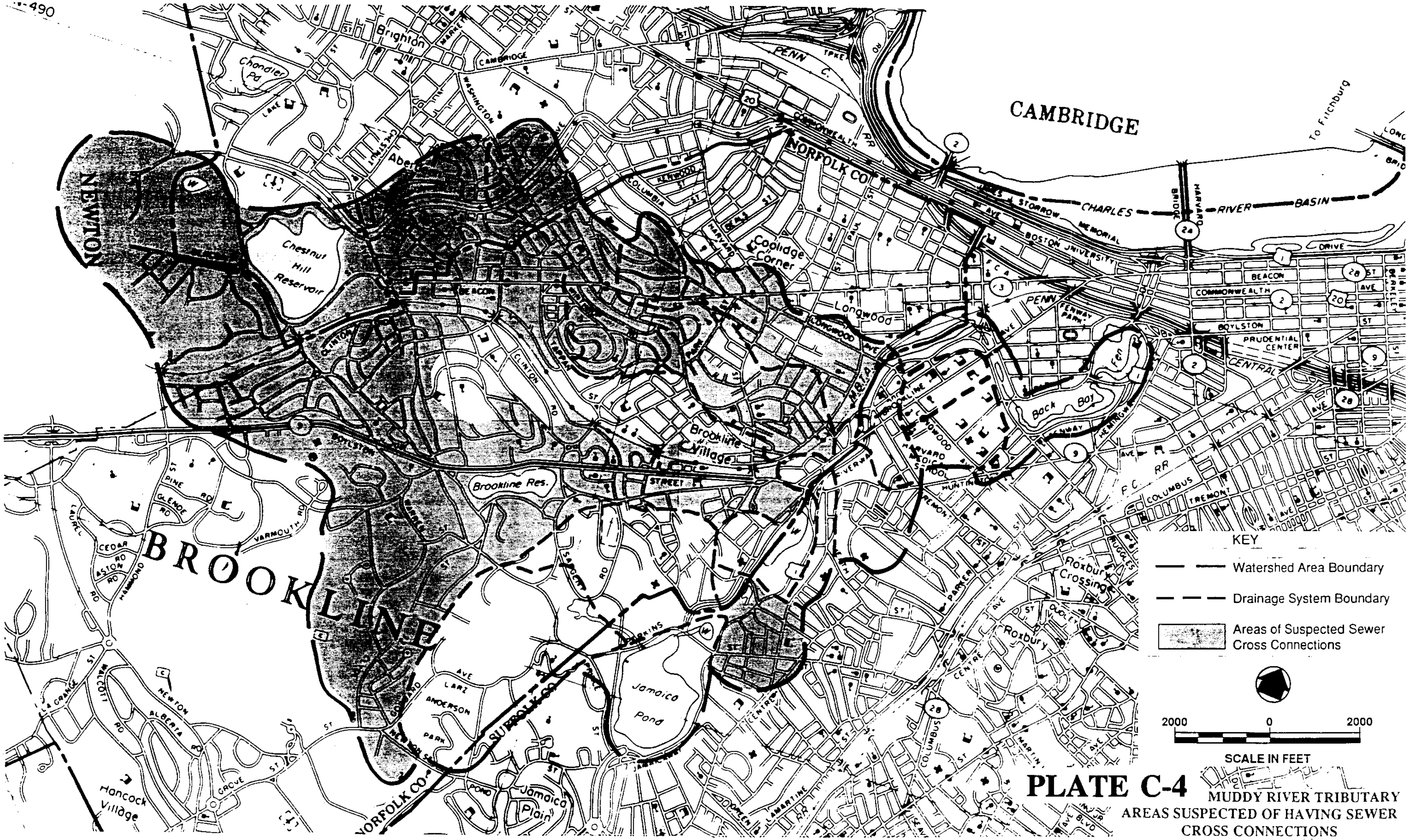


PLATE C-4 MUDDY RIVER TRIBUTARY
AREAS SUSPECTED OF HAVING SEWER
CROSS CONNECTIONS

TAKEN FROM "MUDDY RIVER WATER QUALITY IMPROVEMENT PLAN"
BY METCALF & EDDY, DATED 1990

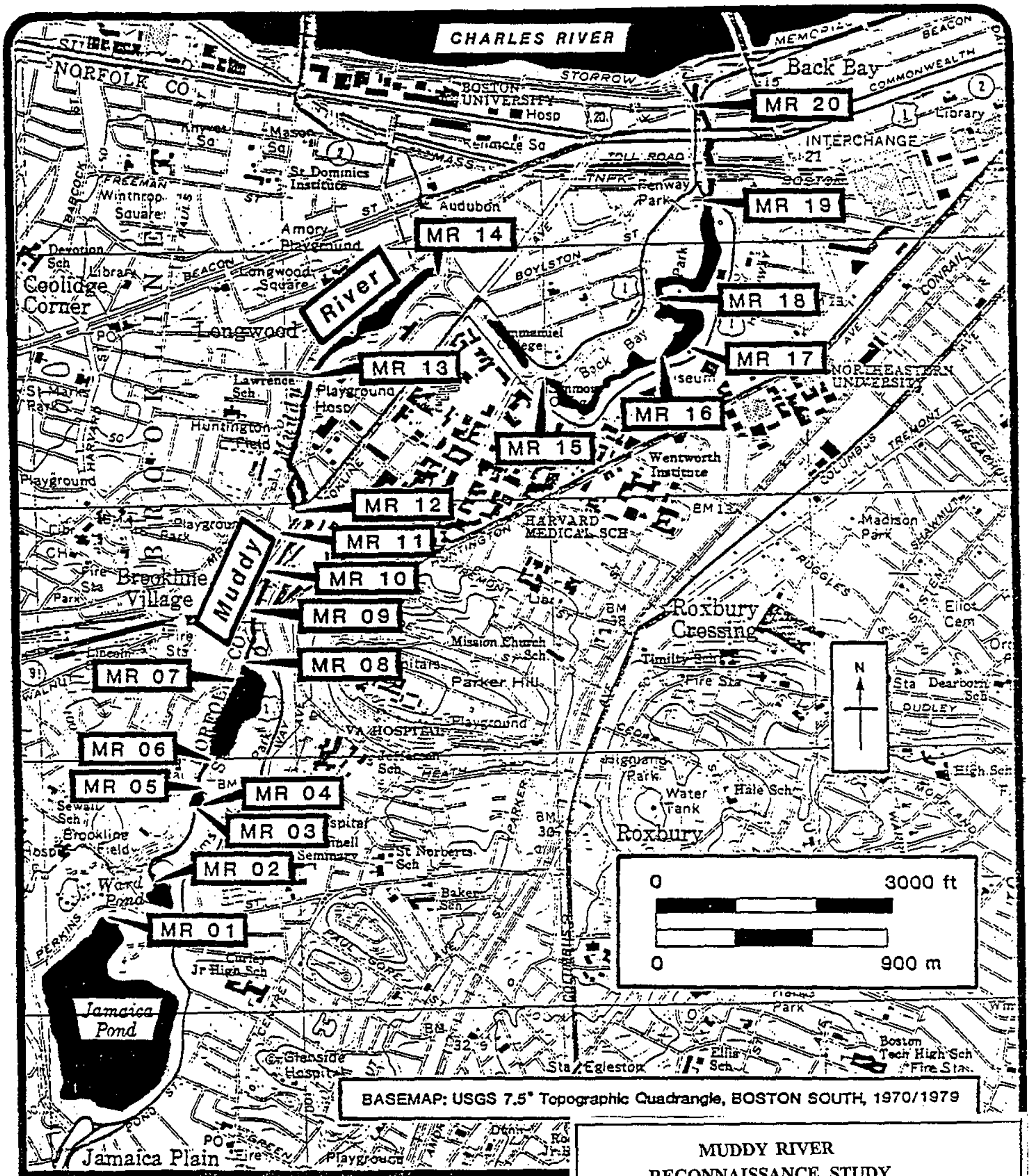
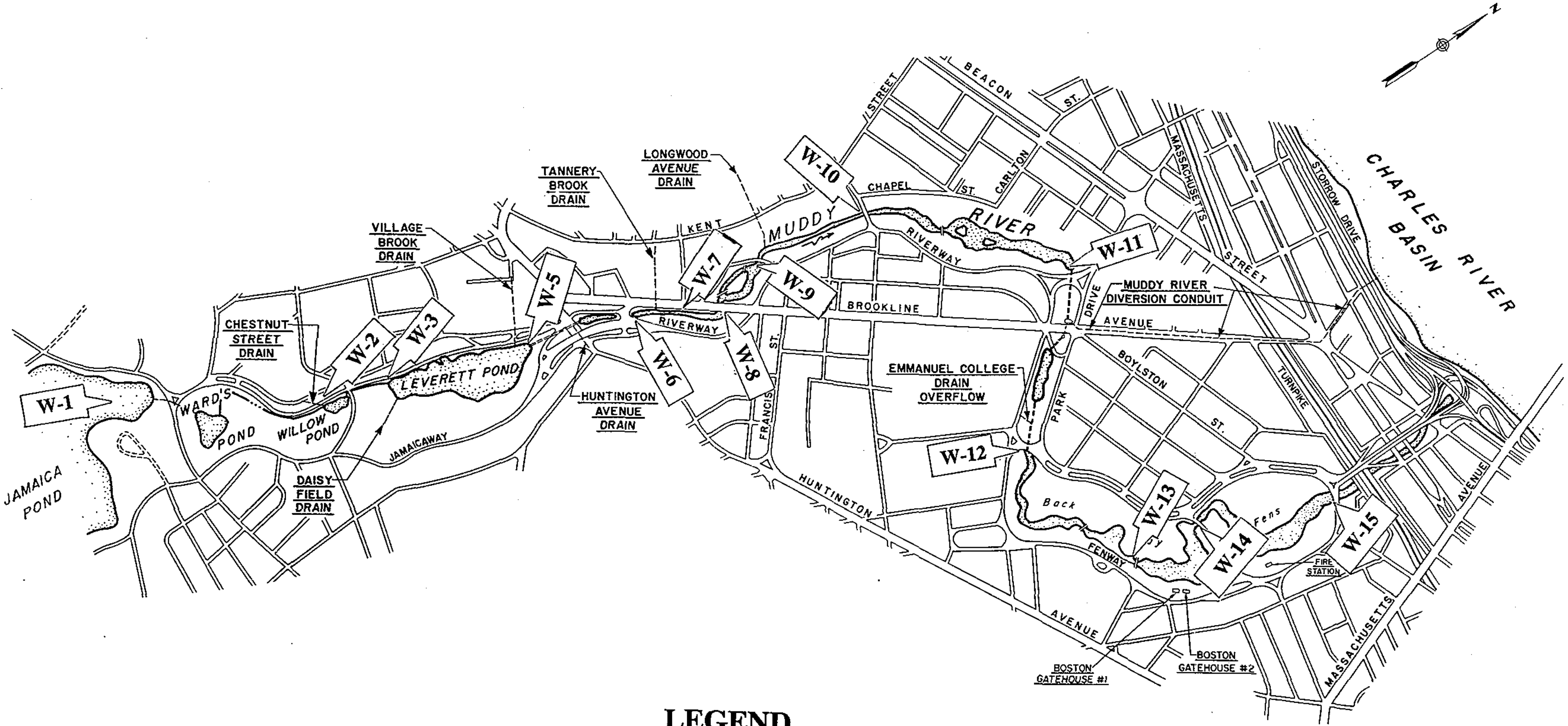


PLATE C-5

MUDDY RIVER
RECONNAISSANCE STUDY
MASSACHUSETTS
DIVISION OF WATER POLLUTION
CONTROL SAMPLING LOCATIONS
1986

HYDRAULICS AND
WATER QUALITY BRANCH
NOVEMBER 1992



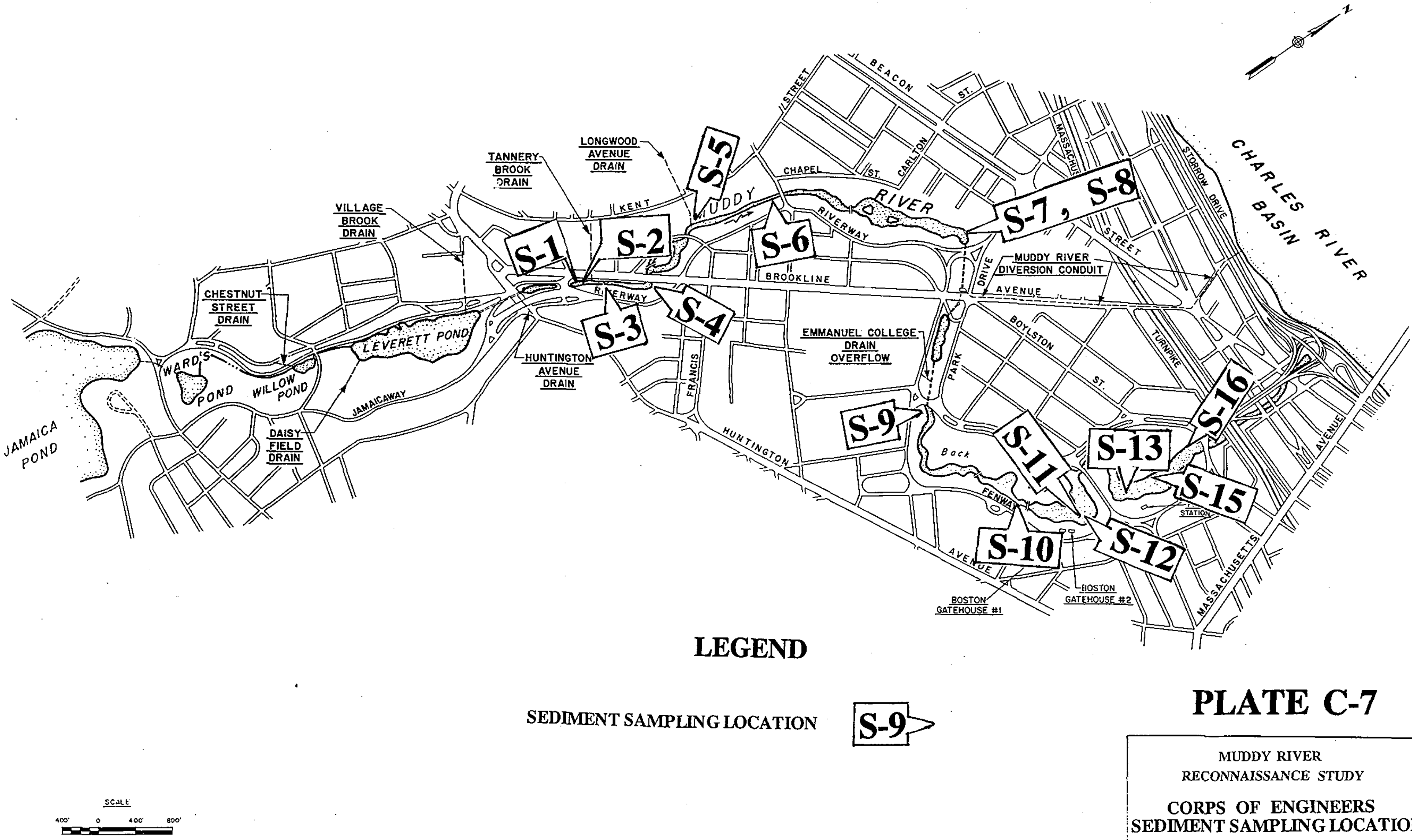
LEGEND

SAMPLING LOCATION – W-1

PLATE C-6

MUDDY RIVER
RECONNAISSANCE STUDY
CORPS OF ENGINEERS
WATER QUALITY
SAMPLING LOCATIONS

HYDRAULICS AND
WATER QUALITY BRANCH NOVEMBER 1992



LEGEND

SEDIMENT SAMPLING LOCATION S-9

PLATE C-7

MUDDY RIVER
RECONNAISSANCE STUDY

CORPS OF ENGINEERS
SEDIMENT SAMPLING LOCATIONS

HYDRAULICS AND
WATER QUALITY BRANCH

NOVEMBER 1992

APPENDIX D: SEDIMENT QUALITY

TABLE OF CONTENTS

INTRODUCTION

This section summarizes the results of Muddy River sediment testing conducted for this study and for previous studies. Testing was conducted to provide information about current conditions in the river and to help determine likely dredged material disposal requirements.

SAMPLING PLAN AND METHODS

Fifteen sediment samples were collected from the Riverway and Back Bay Fens sections of the Muddy River in June of 1992 (see Plate D-1 andTable D-1 for sample locations). Core samples were collected to a depth of about two feet at each station and analyzed for the following parameters:

Parameter	Location	EPA Method
Metals (As, Cd, Cr, Cu, Pb, Ni, Zn)	All Stations	3051, 6010, 7421 7471, 7060
Petroleum Hydrocarbons	All Stations	9071, 418.1
Volatile and Semivolatile Organics (including PAHs)	S-3, S-5, S-11, S-15	3450, 8240, 8270
PCBs	S-1, S-3, S-5, S-10, S-11, S-15	3510, 8080
TCLP Metals	S-3, S-5, S-11, S-15	1311, 6010, 7060 7470, 7740
Grain Size	All Stations	-

PREVIOUS STUDIES

Results of previous Muddy River sediment analysis are summarized in Table D-2. The most extensive sampling was conducted by the Massachusetts Department of Water Pollution Control (MDWPC) in 1973 and 1986. Both MDWPC studies found elevated levels of metals in the Back Bay Fens sediments. The 1986 MDWPC study also sampled upstream of Park Drive, and found elevated metal levels in Willow Pond, Leverett Pond, and the Riverway. Metal levels were generally higher in Willow Pond and Leverett Pond than in the Riverway or Back Bay Fens.

Table D-1
Muddy River Sediment Sampling Stations.

Sample Number	Location
S-1	75' downstream of River Road
S-2	75' downstream of River Road (Phragmites)
S-3	75' downstream of Tannery Brook drain
S-4	30' upstream of Brookline Avenue Bridge
S-5	75' downstream of Longwood Avenue drain
S-6	150' upstream of Longwood Avenue Bridge
S-7	75' upstream of Park Avenue Culvert
S-8	75' upstream of Park Avenue Culvert (Phragmites)
S-9	75' downstream of Avenue Louis Pasteur
S-10	90' upstream of Forsyth Way Pedestrian Bridge
S-11	100' downstream of Boston Gate House
S-12	100' downstream of Boston Gate House (Phragmites)
S-13	near Fire Station
S-14	deleted
S-15	Victory Gardens (Phragmites)
S-16	300' upstream of Boylston Street Bridge

Note: No standing water was present at Station S-2. At other stations water depth ranged from 18" to 50".

Available data concerning the composition of sediments in the Brookline Avenue Gatehouse and Muddy River Conduit is presented inTable D-3. TCLP extracts of sediments from both gatehouse samples contained low to moderate levels of regulated metals and no detectable pesticides or organics. Total petroleum hydrocarbon (TPH), oil and grease, and polychlorinated bipheny (PCB) levels were also low. Cyanide level in one of the gatehouse samples was high (660 ppm). Source of the cyanide is unknown, but is probably the Emmanuel College drain which flows into the gatehouse at Manhole 91. Samples elsewhere from the conduit generally contained elevated levels of petroleum hydrocarbons, oil and grease, TCLP lead, and cyanide.

RESULTS OF 1992 CORPS OF ENGINEERS SAMPLING

Metals and Total Petroleum Hydrocarbons

Metal levels found in Muddy River sediments are presented in Table D-4. Nearly all samples contained highly elevated metal levels according to criteria given in three different sediment classification schemes (see Table D-5). Most samples had highly elevated levels of lead, mercury, copper, and zinc. Chromium levels were moderately to highly elevated, and nickel levels were generally moderately elevated. Cadmium and arsenic levels were difficult to evaluate due to discrepancies among classification schemes. Levels of both, however, were well above natural background concentrations. Urban runoff entering the river via storm drains is the likely cause of elevated lead, zinc, copper, chromium, and nickel levels at most stations.

Total petroleum hydrocarbons levels were also high, ranging from 260 to 16,000 ppm, and averaging 3440 ppm. As with metals, urban runoff is the likely major source of TPH contamination in the river. Naturally occurring organic compounds may also contribute to the high TPH levels.

Stations with the highest metal and TPH levels were generally associated with major storm drains. Levels of most metals and TPH were much higher just downstream of the Longwood drain (Station S-5) than at the nearest upstream station (S-4) or stations situated further downstream (S-6, S-7, S-8). The drain may also be a source of PCBs, but additional sampling is needed to confirm this.

Relatively high lead and petroleum hydrocarbon levels at Station S-2 are likely due to the Huntington Avenue drain and smaller drains which discharge upstream of Route 9. Low contaminant levels and fines content at Station S-1 are anomalous, and may reflect scour caused by narrowing of the open channel at this location by Phragmites.

Relatively low contaminant levels at Station S-3 suggest that the Tannery Brook drain is a less important source of metal and petroleum hydrocarbon loading than the Longwood drain.

Table D-2
Results of Previous Muddy River Sediment Analysis

Parameter	MDWPC, 1973a	MDC, 1982a	MDC, 1982b	MDWPC, 1987a	MWRA, 1988
Arsenic	10.1 (5.0-14.2)	35	1.7	7.6 (1.7-13)	
Cadmium	5.7 (3.6-11)	4.8	2	(<0.8-2.0)	
Chromiumm	110 (18-250)	58	25	23 (5.2-76)	
Copper	300 (210-550)	296	160	129 (36-228)	
Lead	1070 (670-1470)	1359	270	590 (180-1040)	1200-1600
Mercury	5.1 (3.5-9.2)	-	12	0.41 (0.08-0.74)	2.0-2.8
Nickel	34 (22-51)	-	-	19 (7.8-30)	
Zinc	670 (500-100)	9	-	325 (128-520)	
Petrol. Hydr.	-	-	-	-	25.4-38.2
PCBs	-	-	-	-	<2.5
Pesticides	-	-	-	-	<2.5
Sample Locations	Fens	Fens	Fens	Willow Pond to Fens	Fens
Number of Samples	9	1	1b	6	2

Notes: a:Mean values presented with range in parenthesis.
b:Composite of 6 stations

Table D-3: Muddy River Conduit Sediments*

Analyte(s)	Units	Detection Limit	Concentrations: Sample Location — Brookline Ave Gate House	Brookline Ave Gate House Manhole 91	Upstream MA Tpke Manhole 170	Upstream MA Tpke Manhole 171	Under MA Tpke	Upstream Siphon Structure	Siphon Structure	Deerfield St Manhole Z	Deerfield St Manhole Y
TCLP Volatile Organics (VOAS)	ug/L	5–10	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCLP Semi–Volatile Organics (ABN)	ug/L	10–50	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCLP Pesticides	ug/L	0.05–1	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCLP Herbicides	ug/L	0.4–2	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCLP RCRA Metals											
Barium	ug/L	3	318	472	880	1,350	550	620	700	1,280	1,000
Cadmium	ug/L	3	8	16	92	69	7	16	36	25	40
Chromium	ug/L	7	ND	17	ND	21	ND	ND	ND	ND	44
Lead	ug/L	35	239	1,910	5,080	8,950	2,350	3,640	6,730	3,130	10,700
Mercury	ug/L	0.2	ND	0.6	ND	ND	ND	ND	ND	ND	ND
Other	ug/L	–	ND	ND	ND	ND	ND	ND	ND	ND	ND
Petroleum Hydrocarbons	mg/Kg	20	220	610	11,000	20,000	69,500	38,300	3,050	25,000	4,600
Oil and Grease	mg/Kg	20	280	930	13,000	25,000	103,000	53,400	4,750	39,000	5,700
PCB	ug/Kg	100	ND	120	1,900	800	ND	ND	ND	ND	400
Total Solids	%	1	81.1	72.3	55.5	76.1	37.5	53.9	76.1	41.2	79.5
Reactivity											
Cyanide	mg/Kg	6	ND	660	24	320	328	216	72.9	ND	ND
Sulfide	mg/Kg	6	ND	190	ND	320	232	50.5	65.5	ND	ND
Paint Filter Test	–	–	Free Liquid Detected	Free Liquid Detected	Free Liquid Detected	Free Liquid Detected	Free Liquid Detected	Free Liquid Detected	Free Liquid Detected	Free Liquid Detected	Free Liquid Detected

Notes:

ND: none detected

*: from BWSC (1992)

Table D-4
Results of Corps of Engineers Muddy River Sediment Analysis

	Riverway											Back Bay Fens				
Parameter	S-1	S-2c	S-3d	S-4	S-5d	S-6	S-7	S-8c	S-9	S-10	S-11d	S-12c,d	S-13	S-15	S-16d	Mean e
Arsenic	2.1	8.2	17	19	20	19	31	23	21	24	10	30	6.8	14	31	20
Cadmium	0.7	4.6	1.7	1.9	5.2	1.9	1.3	2.2	6.5	4.9	6.2	12	<1.3	7.1	2.8	4
Chromium	17	150	30	46	130	44	37	53	590	38	61	93	30	91	49	103
Copper	56	310	170	230	570	170	220	230	690	240	360	1000	160	340	270	350
Lead	220	1400	410	730	2100	420	350	380	1900	390	1100	1800	490	870	660	930
Mercury	0.2	1.6	0.8	1.6	3.2	0.9	0.2	0.7	6.4	1.4	0.6	1.6	1.4	2	2.2	1.7
Nickel	12	45	28	42	72	32	35	37	100	28	38	52	23	43	35	43
Zinc	130	630	350	460	660	290	360	450	1400	510	720	1500	390	630	770	660
Petrol. Hydr.	530	16000	1400	4000	11000	1300	1200	1800	4200	1400	4400	1500	260	2100	530	3650
PCBs	0.6	-	0.8	-	3.6	-	-	-	-	1.8	2.6	-	-	-	0.3	1.8
% Fines f	<1	62	67	64	50	36	37	30	42	36	19	25	59	49	28	43

Notes: a:Samples collected in June 1992.
b:All values in mg/g unless notes.
c:Sample collected within Phragmites stands
d:Sample analyzed for TCLP metals & volatile & semi-volatile organics.
e:Mean excludes Sample S-1.
f:See Attachment I for grain size curves.

Table D-5 Sediment Classification Schemes

Classification Scheme	Concentration (mg/g)							
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Massachusetts Lakes Study								
Normal	< 25	< 5	< 30	< 70	< 200	< 0.35	< 35	< 250
Elevated	25-50	5-14	30-70	70-130	200-410	0.35-0.75	35-75	250-450
Highly Elevated	> 50	> 14	> 70	> 130	> 410	> 0.75	> 75	> 450
US EPA Region V Criteria								
Nonpolluted	< 3	*	< 25	< 25	< 40	> 1.0	< 20	< 90
Moderately Polluted	3-8	*	25-75	25-50	40-60	> 1.0	20 - 50	90-200
Heavily Polluted	> 8	> 6	> 75	> 50	> 60	*	> 50	> 200
Illinois Lakes Study								
Below Normal	*	*	< 14	*	< 15	*	*	< 50
Normal	< 27	< 1.8	14-30	< 100	15-100	< 0.25	*	50-175
Elevated	27-41	1.8-2.6	30-38	100-150	100-150	0.25-0.40	*	175-250
Highly Elevated	> 41	> 2.6	> 38	> 150	> 150	> 0.40	*	> 250
Crustal Abundance	5	0.06	100	30	10	0.03	40	50

References: US EPA (1977, 1983); Rojko (1991)

* No value given for this category.

Chromium and mercury levels at Station S-9 were much higher than at any other location in the Riverway or Fens. These levels may result from overflow discharge of the Emmanuel College drain into the culverts upstream of S-9. The drain normally discharges inside the Muddy River conduit near the Brookline Avenue Gatehouse and may also be responsible for TCLP mercury and cyanide detected in sediments at "Manhole 91" (see Table D-3). Existing or historic cross connections between the Emmanuel Drain and sewerlines servicing university or hospital laboratories are a possible source of the mercury, chromium, and cyanide. Additional testing of sediments from Station S-9 for cyanide is needed.

Elevated metal and petroleum hydrocarbon levels in the Southern Basin (Stations S-11 and S-12) probably reflect loading by the Stony Brook discharge.

Volatile and Semivolatile Organics

A variety of polyaromatic hydrocarbons (PAHs), other semi-volatile organics, and volatile organics were detected in sediments from near the Tannery Brook, Longwood Avenue, and Stony Brook discharges (Table D-6).

Total PAH concentrations ranged from 71 to 264 ppm. Pyrene, flouranthene, chrysene, benzo(a)anthracene, and phenanthrene were most abundant among the 18 PAHs detected. PAHs in the Muddy River are probably largely derived from automobile and diesel exhaust, and reach the river in urban runoff.

Total PAH levels in Muddy River sediments were much higher than usually reported for coastal marine or fresh water sediments (Johnson and Larsen, 1985; Metcalfe et al. 1988). Levels are higher than reported for several rivers in eastern Massachusetts (U.S. Army Corps of Engineers, 1990; Shiaris and Jambard-Sweet, 1986).

Several pthaltes, with concentrations ranging up to 20 ppm were detected (Table D-6). These are likely to be breakdown products of plastic wastes. Other semi-volatile organics and volatile organics were found in very low (< 0.5 ppm) concentrations.

PCBs

PCB levels in Muddy River sediments ranged from 0.3 to 3.6 (Table D-4). These levels are moderately elevated compared to levels commonly reported in other eastern Massachusetts Rivers. PCB levels, however, are well below levels reported in heavily contaminated reaches of the Millers, Housatonic, and Hudson Rivers. Source of the PCBs is unknown, but may be contaminated oils discharged years ago into the sewer system or storm drains. PCBs are persistent in the environment, and significant loading may no longer be occurring.

Table D-6
Volatile and Semi-volatile Organics Detected in Muddy River Sediments

Parameter	Station S-3	S-5	S-11	S-14
PAHs (mg/g)				
pyrene	65	32	29	19
fluoranthene	25	10	12	5.2
phenanthrene	22	9.6	13	2.2
chrysene	24	9.1	7.2	4.9
benzo(a)anthracene	24	7.3	6.3	4.3
indeno(1,2,3-cd)pyrene	18	6.4	4.1	7.0
benzo(k)fluoranthene	18	5.6	5.8	6.1
benzo(b)fluoranthene	17	5.4	5.6	5.9
benzo(a)pyrene	16	5.5	5.1	4.9
benzo(g,h,i)perylene	13	5.6	5.6	6.7
anthracene	6.5	2.3	2.3	1.2
dibenz(a,h)anthracene	3.8	1.0	1.0	0.9
dibenzofuran	3.0	0.9	1.4	0.5
fluorene	2.4	1.7	1.9	0.8
napthalene	2.6	0.7	1.6	0.5
acenaphthene	1.9	1.2	1.4	0.3
2-methylnapthalene	1.3	0.6	1.1	0.4
acenaphthylene	0.3	0.2	0.2	0.4
Total PAHs	264	105	104	71
Other Semi-Volatile Organics (mg/g)				
1,4-dichlorobenzene	0.10	0.22	0.32	-
1,2-dichlorobenzene	-	-	0.25	0.23
2-methylphenol	0.10	-	-	-
4-methylphenol	0.40	0.44	-	-
diethylphthalate	0.10	0.09	0.32	-
di-n-butylphthalate	0.31	0.29	20	1.2
butylbenzylphthalate	-	0.51	-	-
bis(2-ethylhexyl)phthalate	1.9	6.7	7.7	1.8
Volatile Organics (mg/g)				
Acetone	0.26	0.47	0.31	0.22
Carbon disulfide	0.01	0.01	0.01	0.01
Methylene chloride	0.05	0.04	0.06	0.11
2-butanone	0.08	0.17	0.12	0.10
toluene	-	0.01	-	-
O-Xylene	-	0.01	0.01	-

See Attachemnt II for complete analytical report.

TCLP Analysis

Results of TCLP analysis of Muddy River sediments are summarized in Table D-7. TCLP metal levels were below regulatory limits in all samples. TCLP analysis for regulated volatile and semi-volatiles organics was not required since absolute levels of these contaminants in Muddy River sediments were low (see Table D-6 and Attachment II).

ECOLOGICAL RISK ASSESSMENT

Although a detailed ecological risk assessment of Muddy River sediments is beyond the scope of this study, a few observations concerning the biological significance of sediment contamination can be made.

Levels of some contaminants found in Muddy River sediments exceed threshold levels likely to have an adverse effect on aquatic life (see Table D-8). At a minimum, fish and other aquatic life in the river are likely to experience a variety of sublethal effects due to contact with the sediments. Some sediments, particularly those with high TPH, PAH, and lead levels are likely to be acutely toxic. PAH levels also well exceed levels likely to cause carcinomas in fish.

Elevated PCB levels in sediments have resulted in high levels of PCB in fish from the river (see Appendix E). Fish probably accumulate PCBs largely due to direct ingestion of sediments and contaminated prey.

High levels of mercury, lead, chromium, copper, and zinc in Muddy River sediments have not resulted in correspondingly high metal levels in fish tissue (see Appendix E). This finding agrees with other studies which indicate that lead, chromium, copper and zinc do not biomagnify in food aquatic food chains to any great degree (Kay, 1984). Mercury levels in fish from the river are relatively low despite high mercury levels in sediments. Mercury readily biomagnifies in aquatic food chains, and further sampling is advisable to confirm that fish in the river do not contain elevated mercury levels.

SEDIMENT DISPOSAL OPTIONS

Options for disposing of sediments dredged from the Muddy River include in-state or out-of-state solid waste landfills, asphalt batching, and incineration. The method chosen would depend on sediment composition, state dredged material and solid waste disposal regulations and policies, the willingness of disposal facilities to accept the material, and cost.

Massachusetts guidelines for upland dredged material disposal are presented in Table D-9. Sediments classified "Type I" are suited for unconfined upland disposal. Those meeting Type II standards are classified as solid waste and are suitable for use as daily cover in landfill. Sediments failing to meet Type II criteria but which meet TCLP limits are considered solid waste. Sediments failing to meet TCLP limits would be considered a RCRA hazardous waste. Muddy River sediments fail to meet Class II guidelines because of high lead levels, but pass TCLP analysis, and would be considered solid waste.

Under current Massachusetts DEP solid waste disposal policy, sediment with less than 3000 ppm TPH could be disposed in a state licenced solid waste landfill. Several such landfills are situated near Boston. Disposal costs, including transport, would be about 75 dollars per ton.

Massachusetts DEP policy prohibits disposal of material with greater than 3,000 ppm TPH at in-state solid waste landfills unless the hydrocarbons are of natural (non petroleum) origin. Such material would need to be disposed at an in-state asphalt batching plant, out-of-state solid waste landfill, or incinerated. The nearest out of state landfill which would accept solid waste with elevated TPH levels is situated near Augusta, Maine. Cost to dispose dredged material from the Muddy River at this landfill would be about 500 dollars per ton (BWSC, 1992). The nearest asphalt batching plants which might accept Muddy River sediments are located in Stoughton, Dracut, and Marlboro, Massachusetts. Cost to dispose of material at batching plants would probably be comparable to in-state landfilling. Batching plants might be unwilling to accept the sediments, however, due to elevated PCB, PAH, and lead levels (Buckley, 1992). Further coordination with the Massachusetts DEP and batching plant operators would be necessary to determine if batching is a viable option. Finally, sediments could be incinerated at a facility in North Adams, Massachusetts. Cost of this option would likely be higher than out of state landfilling.

The available data suggests that sediments in many areas of the Riverway and Fens contain less than 3000 ppm TPH and could be disposed of at an in-state solid waste landfill. Sediments near major drains, however, are likely to have TPH levels greater than 3000 ppm and would require disposal at an out-of state landfill or an asphalt batching plant. If out of state disposal were necessary, it would probably be cost effective to dredge and dispose of sediments with average TPH levels below 3000 ppm separately from sediments with high TPH levels. More extensive testing of Muddy River sediments would be needed during the Feasibility Phase to delineate areas with high TPH levels. Existing data, however, suggests that perhaps two-thirds of the surface sediments have TPH levels below 3000 ppm and could be disposed at an in-state landfill. If disposal of sediments with high TPH levels proved too costly, substantial environmental benefits might still be gained by selectively dredging only areas with average TPH levels below 3,000 ppm.

Sediment removed from the Brookline Avenue gatehouse during enlargement or removal of the Park Street culverts would be considered solid waste and could be disposed at an in-state landfill. The work would not require removal of highly contaminated sediments situated in Manhole 91 or elsewhere in the Muddy River conduit.

Table D-7: Summary of Muddy River Sediment TCLP Analysis

Parameter	Regulatory Level	S-3	S-5	S-11	S-15
Silver	5.0	< 0.21	< 0.21	< 0.21	< 0.21
Arsenic	5.0	< 0.04	< 0.03	< 0.02	< 0.04
Barium	100	0.51	0.46	0.45	0.33
Cadmium	1.0	0.02	0.07	0.08	0.03
Chromium	5.0	0.01	0.02	< 0.01	< 0.01
Lead	5.0	0.86	3.8	2.9	1.6
Selenium	1.0	< 0.01	< 0.01	< 0.01	< 0.01
Mercury	0.2	< 0.0004	< 0.0004	< 0.0004	< 0.0004

Notes:

a: All values in mg/l.

b. Regulatory levels are given at 40 CFR 261.

Table D-8
Apparent threshold levels for selected chemicals in sediments having an adverse effect on aquatic life.[a,b]

Parameter	Threshold Level	Muddy River Mean
Arsenic	50	20
Cadmium	5	4
Chromium	NA	103
Copper	300	350
Lead	300	930
Mercury	1	1.7
Nickel	NA	43
Zinc	260	660
Total PCBs	0.37	1.8
Total PAHs	22	136

Notes:

a: Adapted from NOAA (1991). Values are largely based on studies of estuarine and marine life and should be extrapolated to freshwater life with caution.

b: All values in mg/g.

NA: Threshold level not available.

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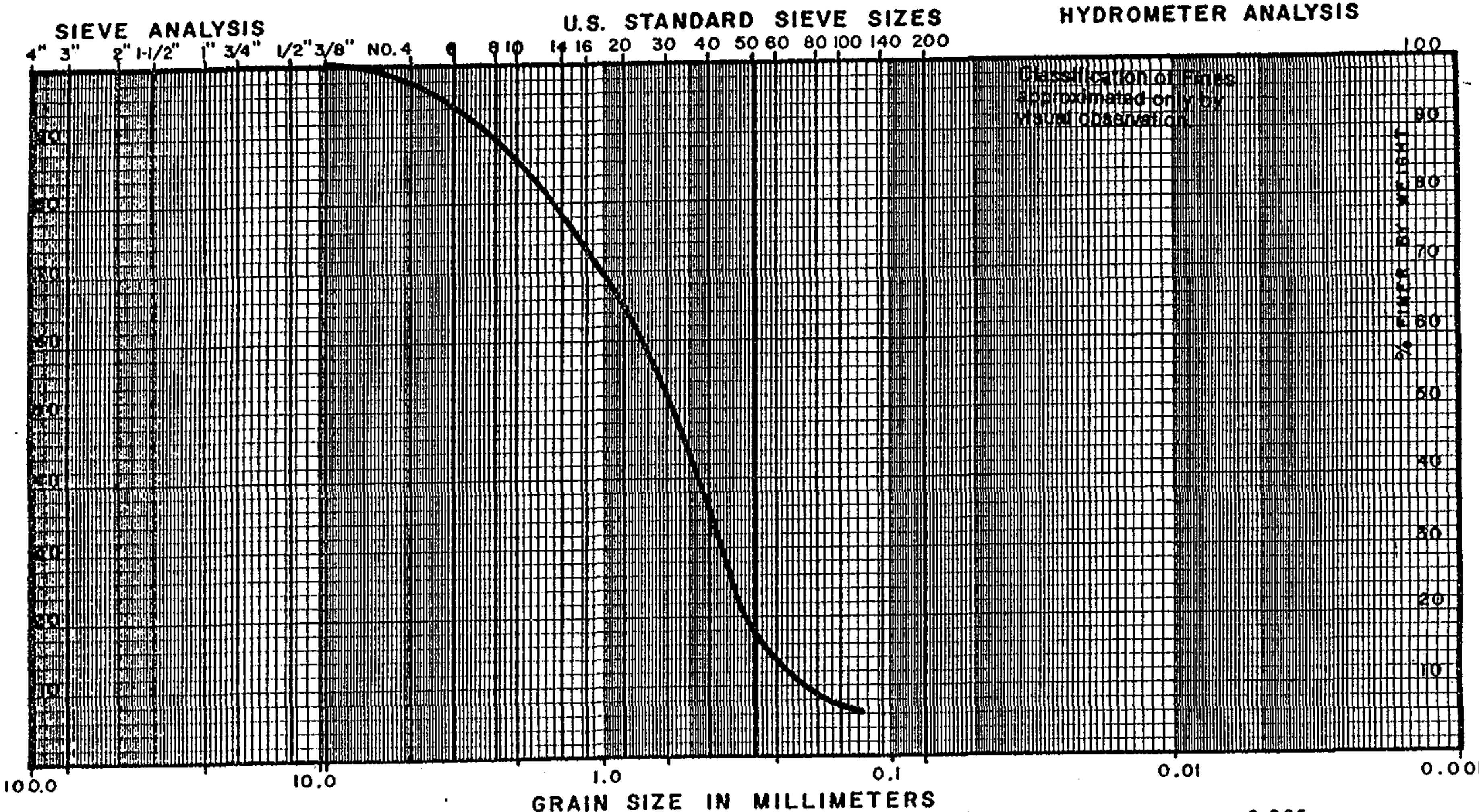
ATTACHMENT I



3"	1"	3/8"	2.0 MM.	0.59	0.25	0.074	0.005

COBBLES	GRAVEL			SAND			SILT	CLAY
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE		

MECHANICAL ANALYSIS

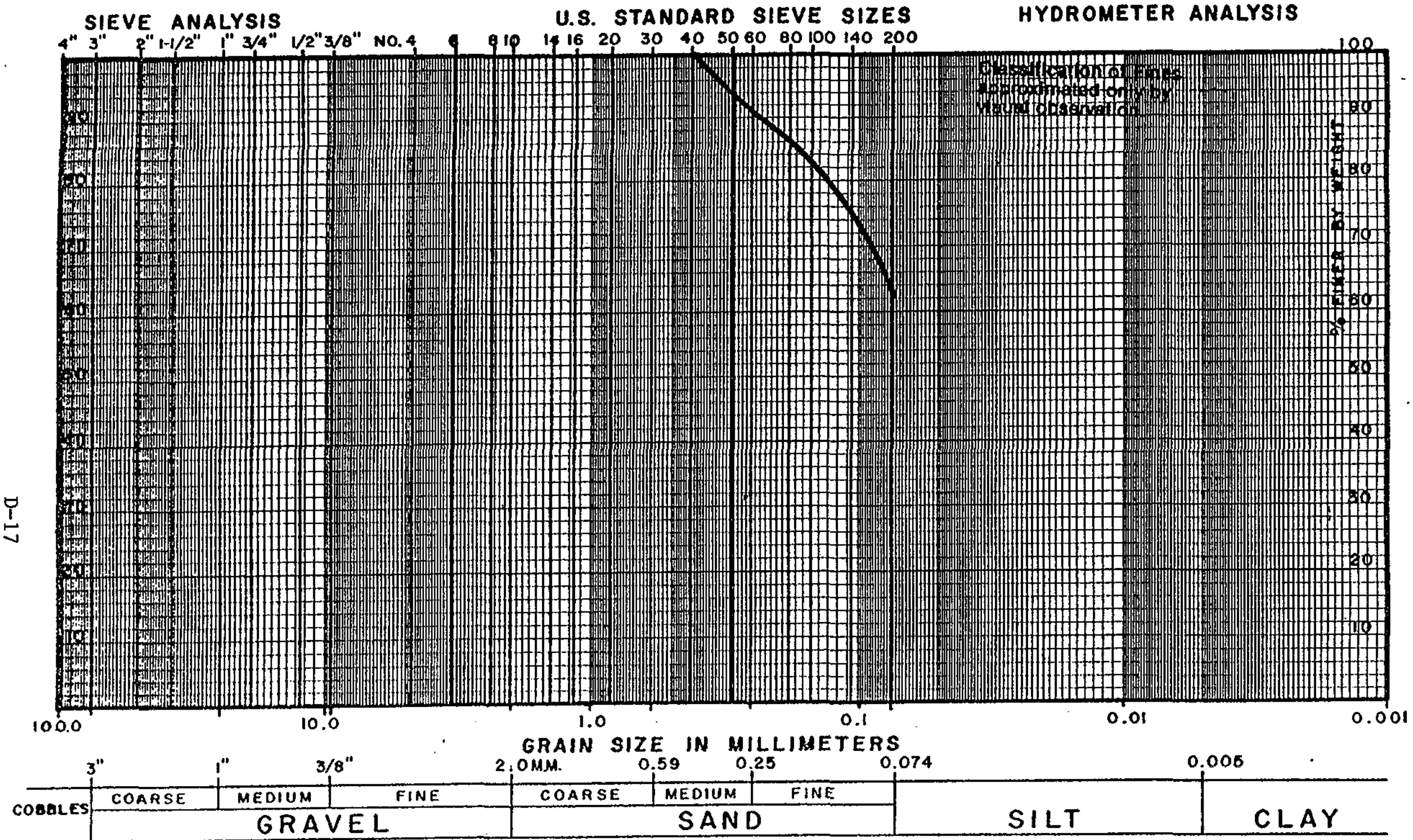
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L.%	P.I.
17212		Dark brown coarse to fine SAND, trace Silt, little fine Gravel (DECOMPOSED WOOD, LEAVES, VEGETATION, GLASS, ODOR.)				

SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 23



D-17

MECHANICAL ANALYSIS

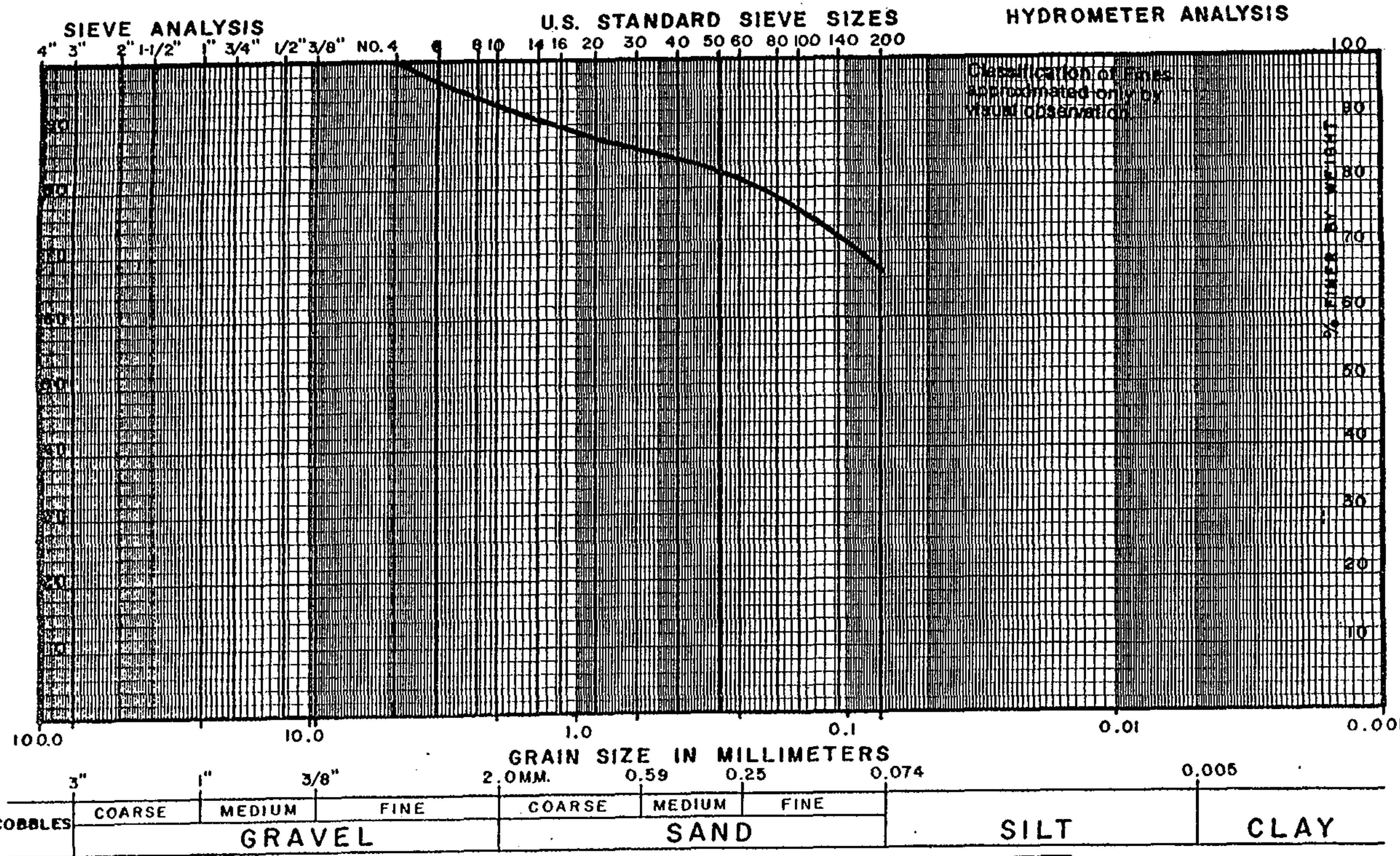
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L. %	P.I.
17213		Dark Grayish brown SILT and f-~~coarse~~ to fine sand (DECOMPOSED WOOD, LEAVES, WOOD CHIP, ROOT.)				

SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 21



MECHANICAL ANALYSIS

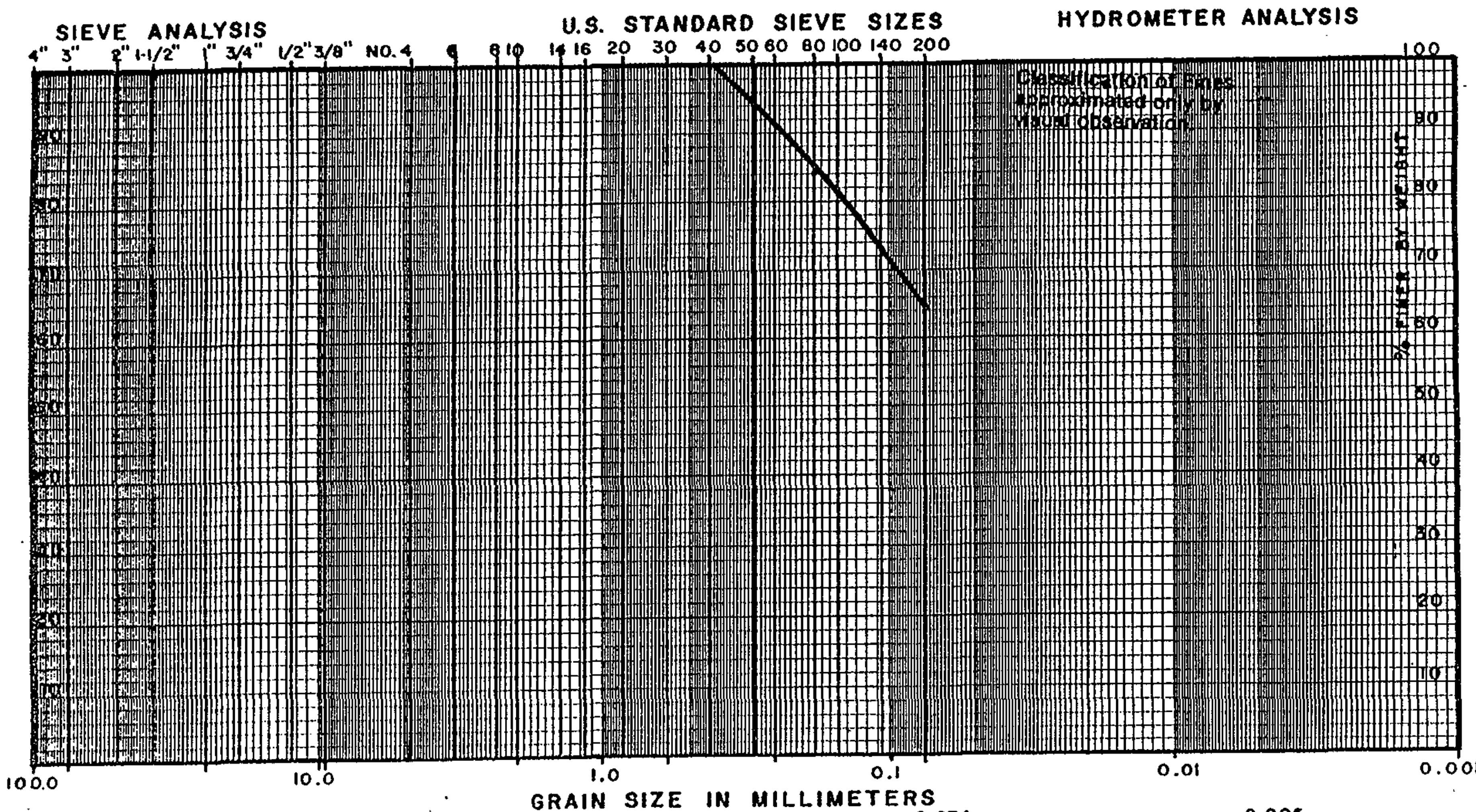
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L.%	P.I.
17214		Dark Grayish brown SILT some(+), coarse to fine Sand, trace fine Gravel (DECOMP. WOOD WOOD CHIPS, LEAVES, GLASS, VEGETATION, ODOR)				

SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 25



	3"	1"	3/8"	2.0MM.	0.59	0.25	0.074	0.006
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

MECHANICAL ANALYSIS

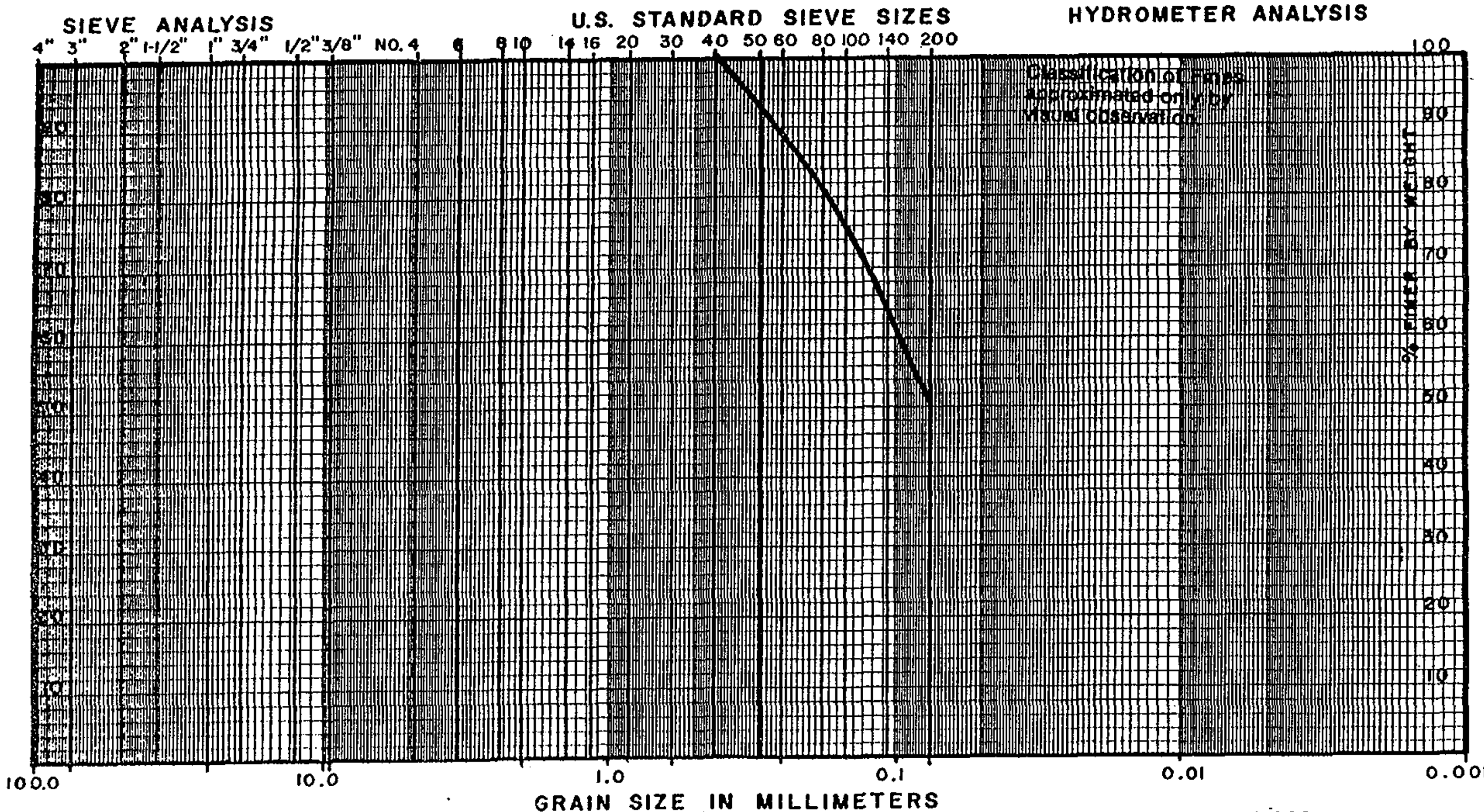
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L.%	P.I.
17215		Dark Grayish brown SILT and(-) coarse to fine sand (DECOMP. WOOD, WOOD CHIPS, LEAVES, ODOR)				

SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 26



	3"	1"	3/8"	2.0MM.	0.59	0.25	0.074	0.005
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

MECHANICAL ANALYSIS

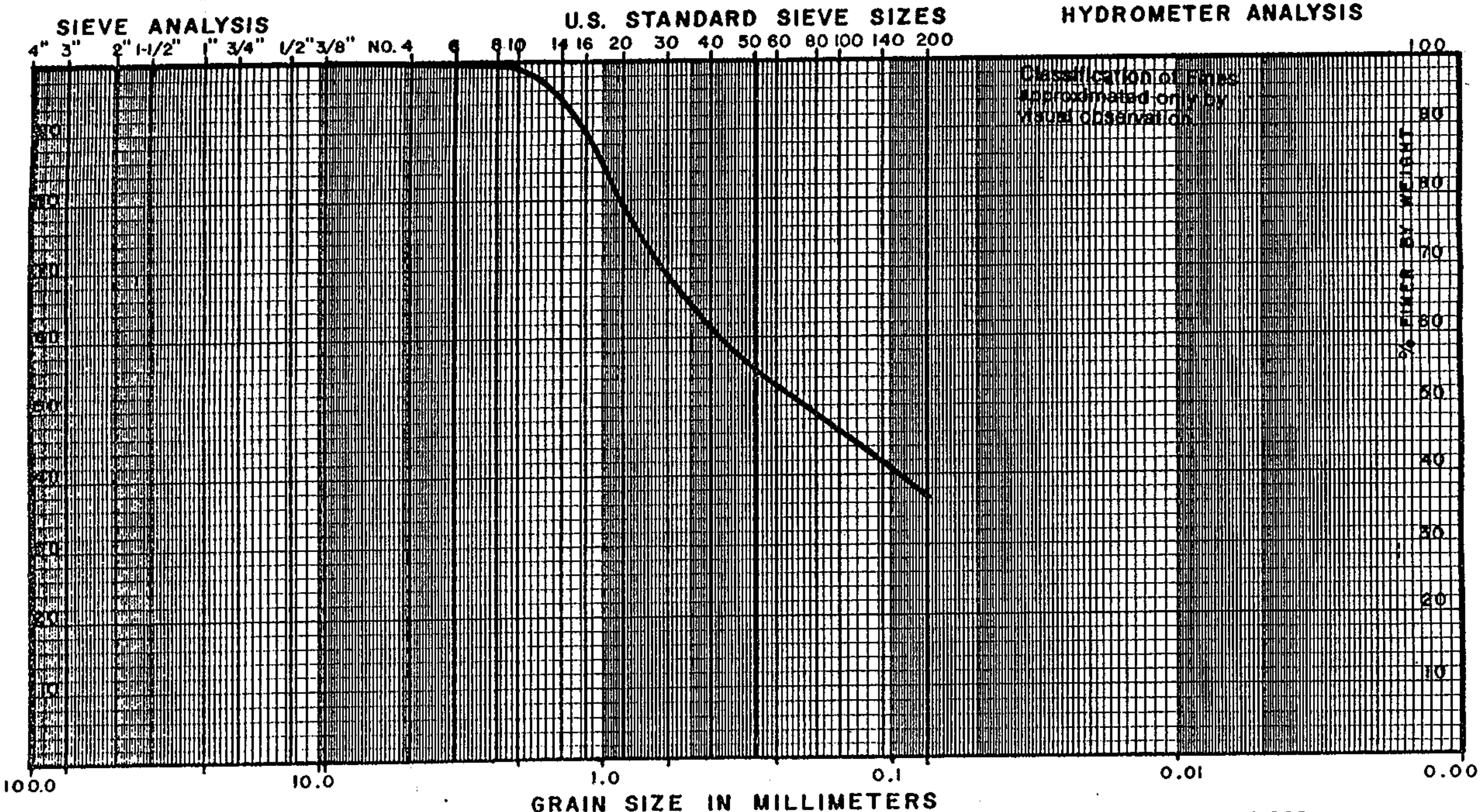
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L.%	P.I.
17216		Dark Grayish brown SILT and (+), coarse to fine sand. (DECOMPOSED WOOD, WOOD CHIPS, ODOR)				

SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 27



3"	1"	3/8"	2.0MM.	0.59	0.25	0.074	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE		
	GRAVEL			SAND			SILT	CLAY

MECHANICAL ANALYSIS

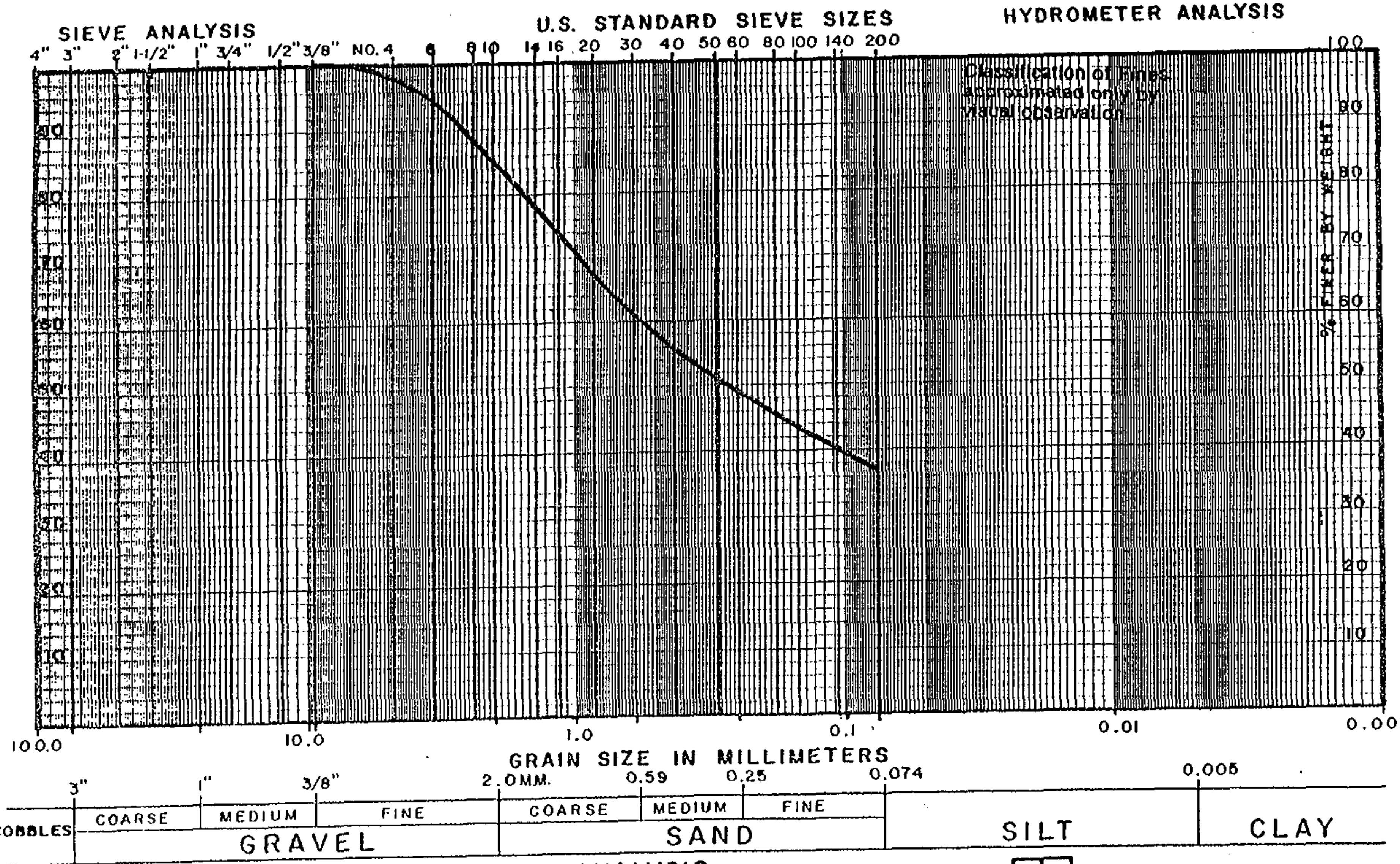
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L.%	P.I.
17217		Dark Gray coarse to fine Sand, and(-) Silt. (DECOMPOSED WOOD, WOOD CHIPS, WOOD, ODOR)				

SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 28



MECHANICAL ANALYSIS

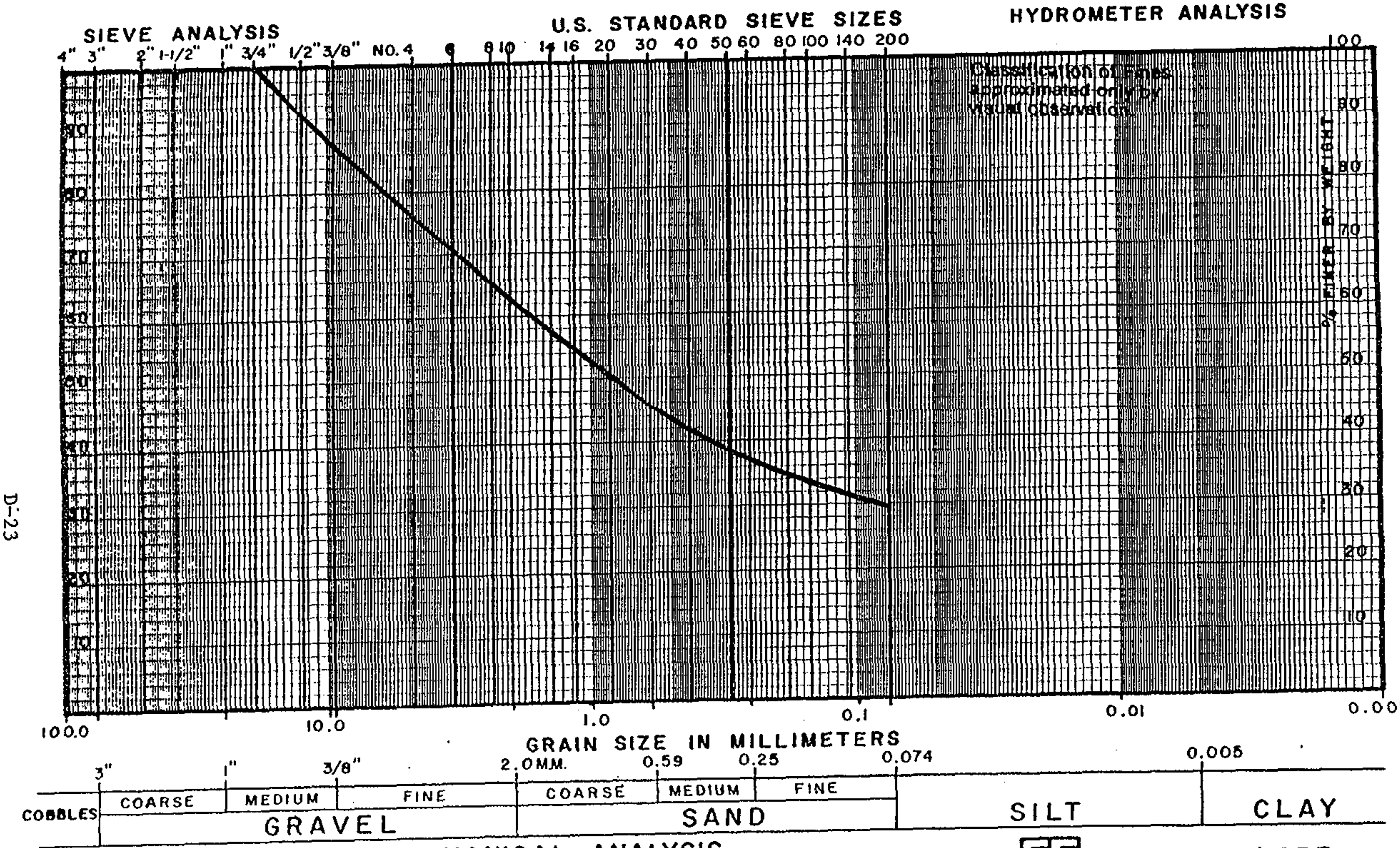
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L. %	P.I.
17167		Dark Gray coarse to fine Sand, and Silt, little fine Gravel (WOOD CHIPS, ODOR)				

SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 22



MECHANICAL ANALYSIS

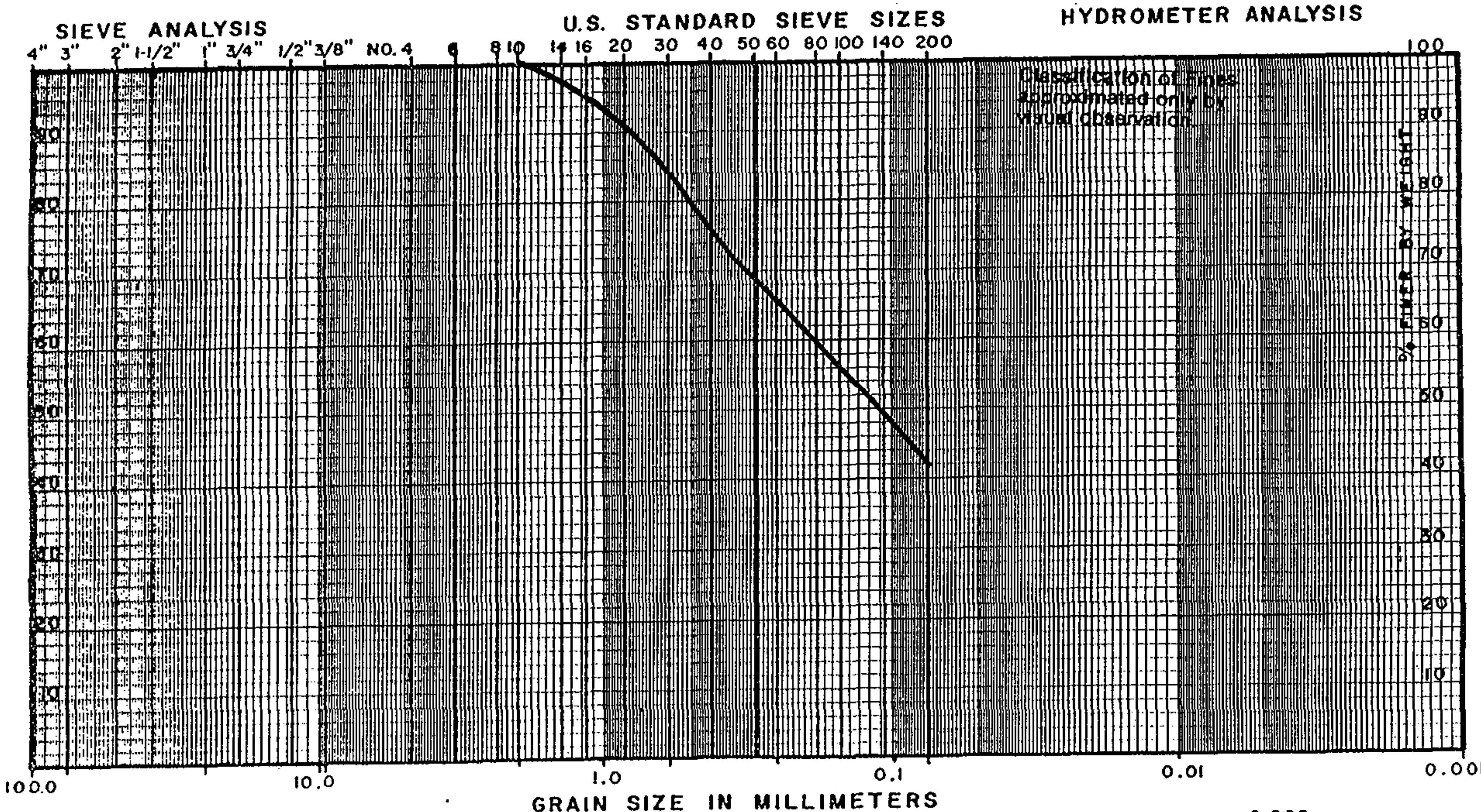
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L.%	P.I.
17168		Dark Gray coarse to fine Sand, some Silt, and (-) medium to fine Gravel. (DECOMP. WOOD, WOOD CHIPS, ORGA				

SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 20



3"	1"	3/8"	2.0MM.	0.59	0.25	0.074	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

MECHANICAL ANALYSIS

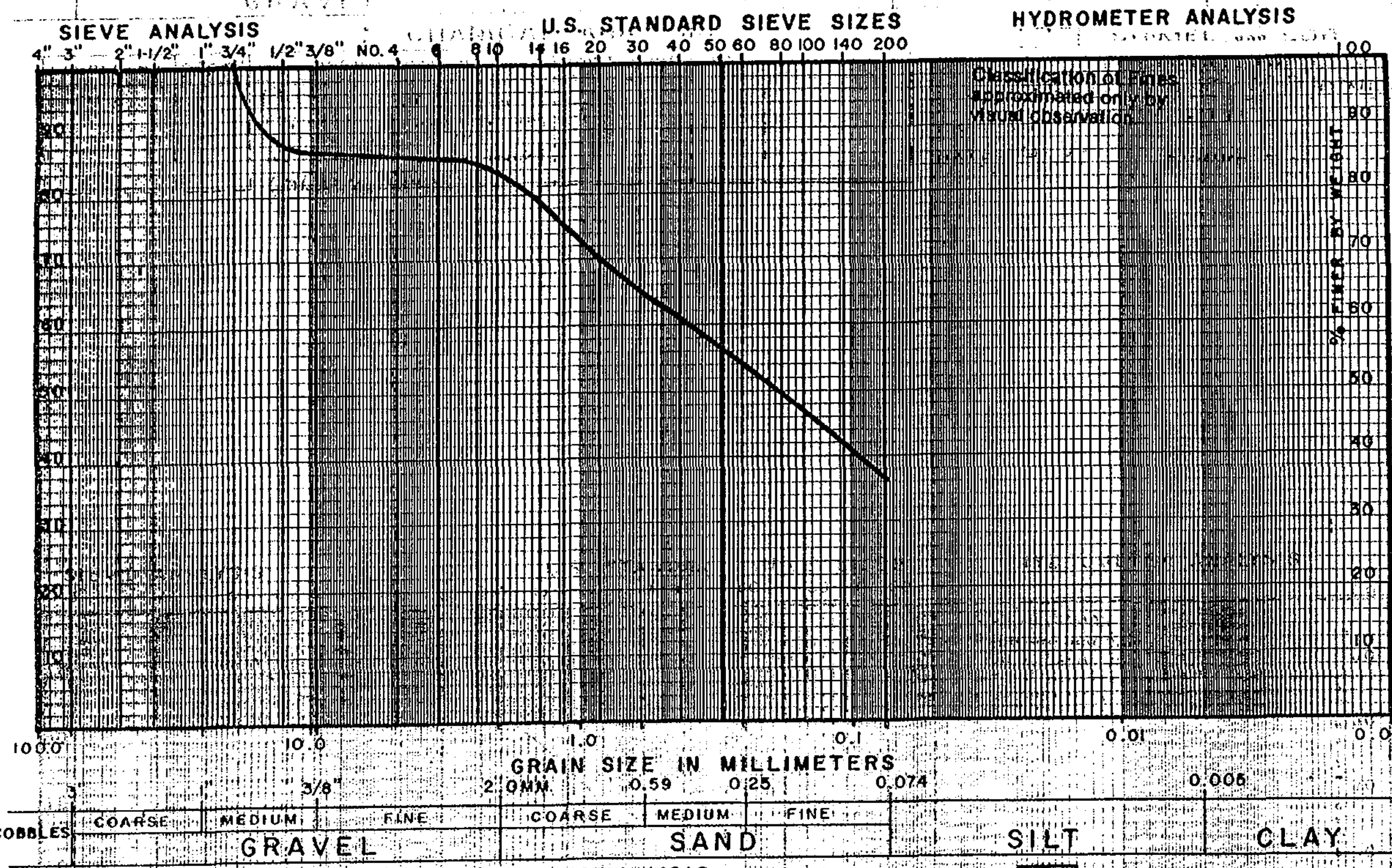
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L. %	P.I.
17169		Dark Gray coarse to fine SAND, and Silt. (LEAVES, WOOD CHIPS, DECOMPOSED WOOD, ODOR)				

SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 1



MECHANICAL ANALYSIS

SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L. %	P.I.
17170		Dark Grayish brown coarse to fine Sand and Silt, little medium to fine Gravel (GLASS, ODOR)				

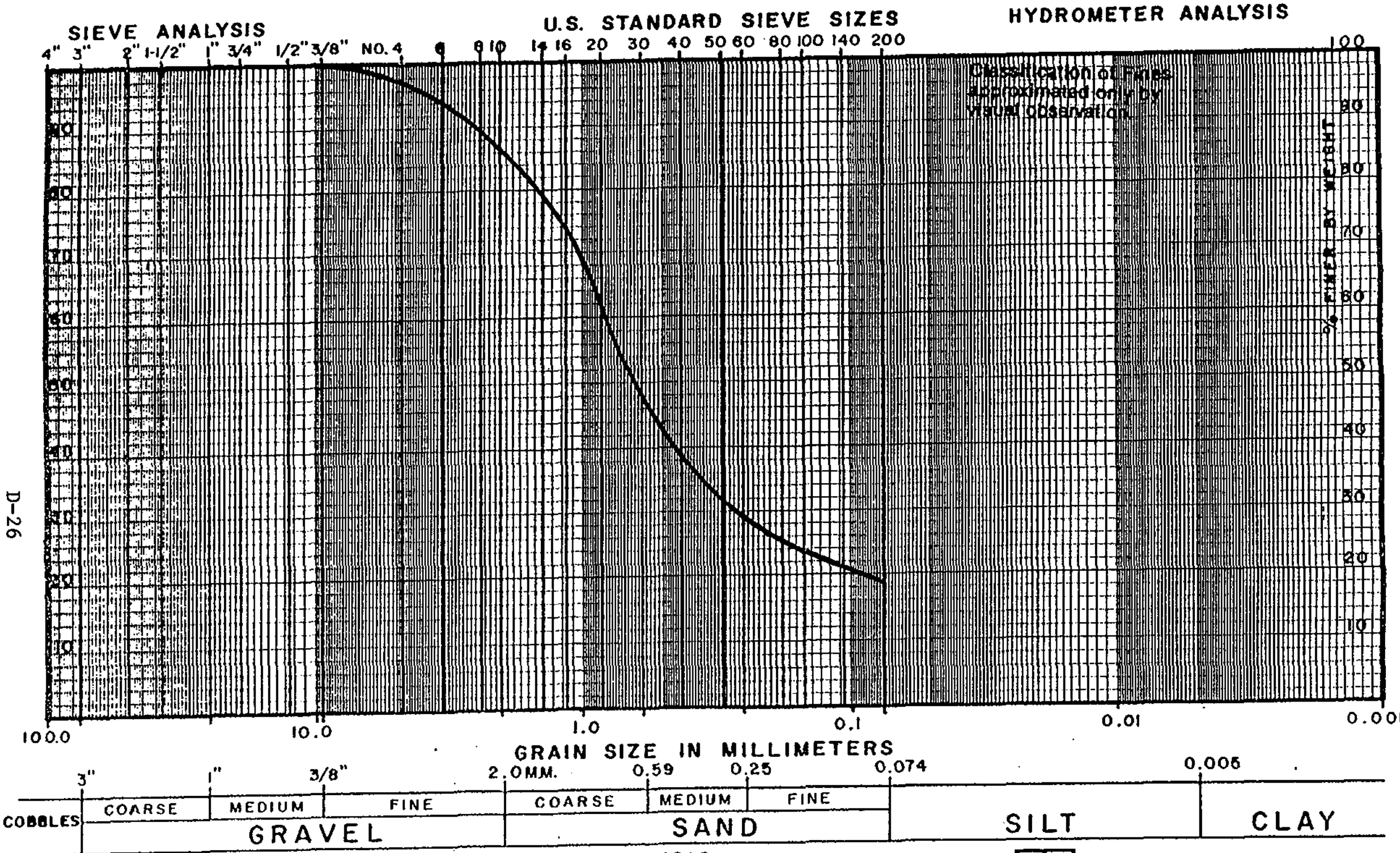
SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. ______

D-26



MECHANICAL ANALYSIS

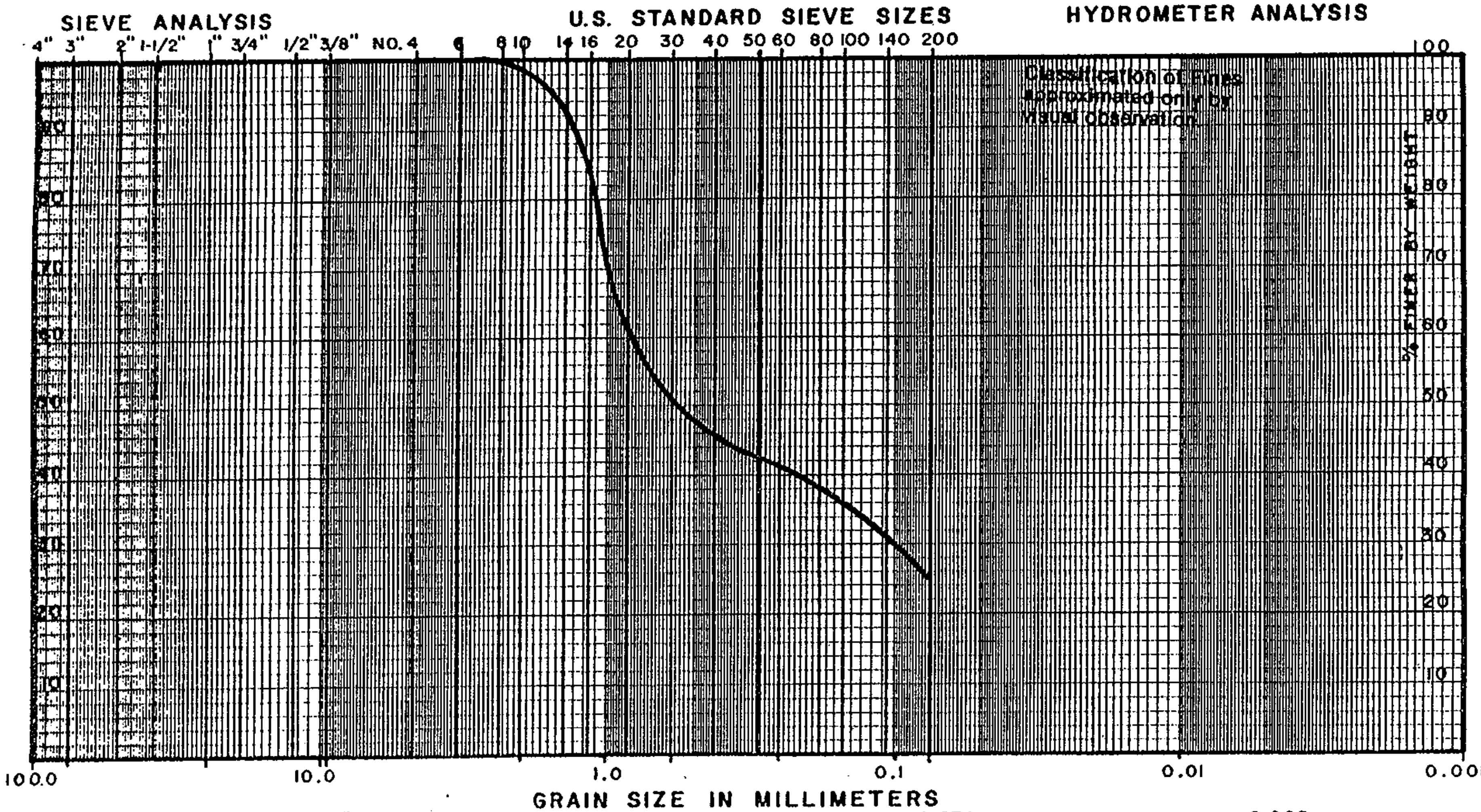
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L. %	P.I.
17171		Dark Grayish brown coarse to fine SAND, little (+) Silt, little fine Gravel. (WOOD CHIPS, LEAVES & ODOR)				

SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 33



3"	1"	3/8"	2.0MM.	0.59	0.25	0.074	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE		
	GRAVEL			SAND			SILT	CLAY

MECHANICAL ANALYSIS

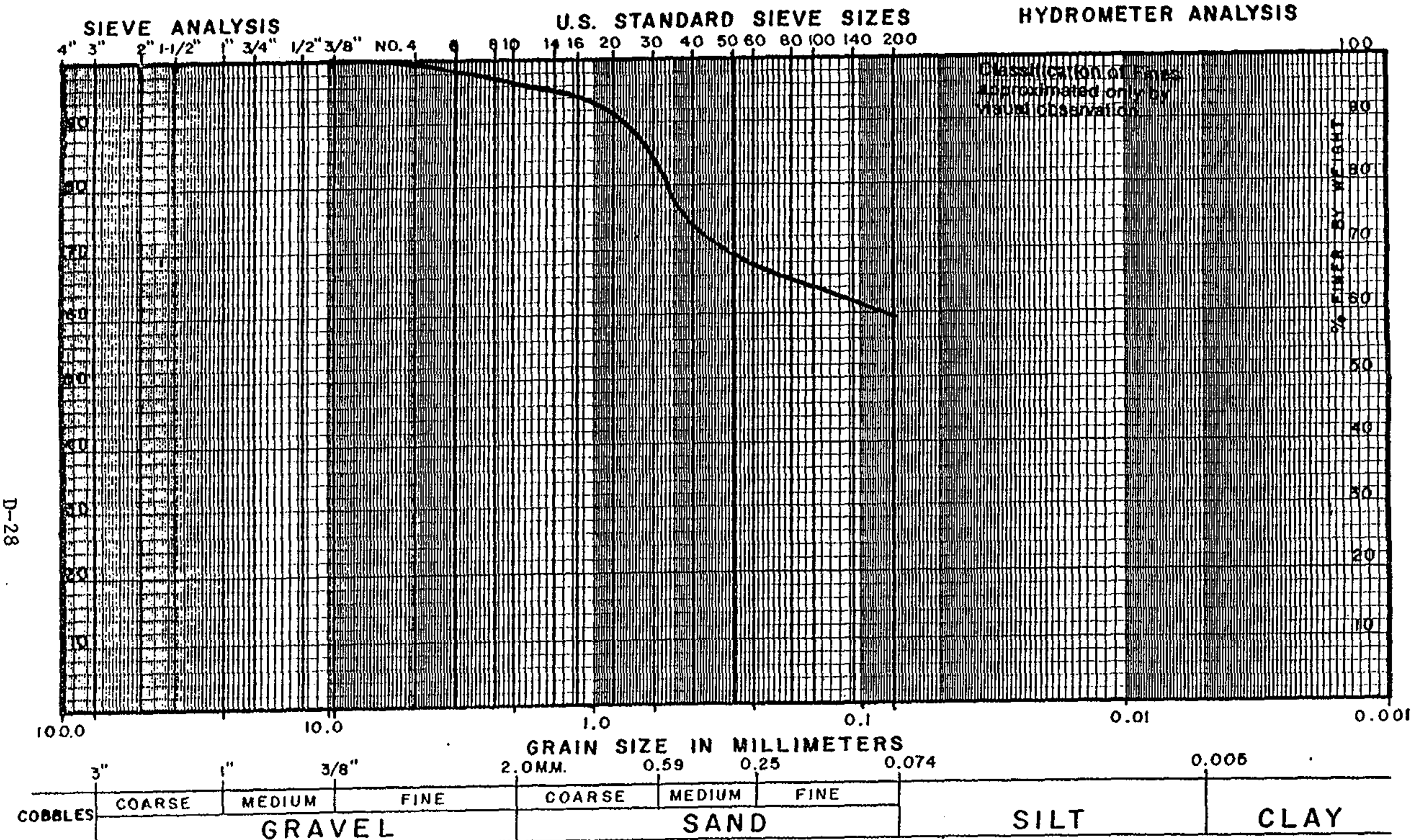
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L.%	P.I.
17172		Dark Grayish brown coarse to fine SAND, some silt (DECOMP. WOOD, WOOD CHIPS & ODOR)				

SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 4



MECHANICAL ANALYSIS

SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L.%	P.I.
17173		Dark Gray SILT and, coarse to fine Sand, trace fine Gravel (DECOMPOSED WOOD & ODOR)				

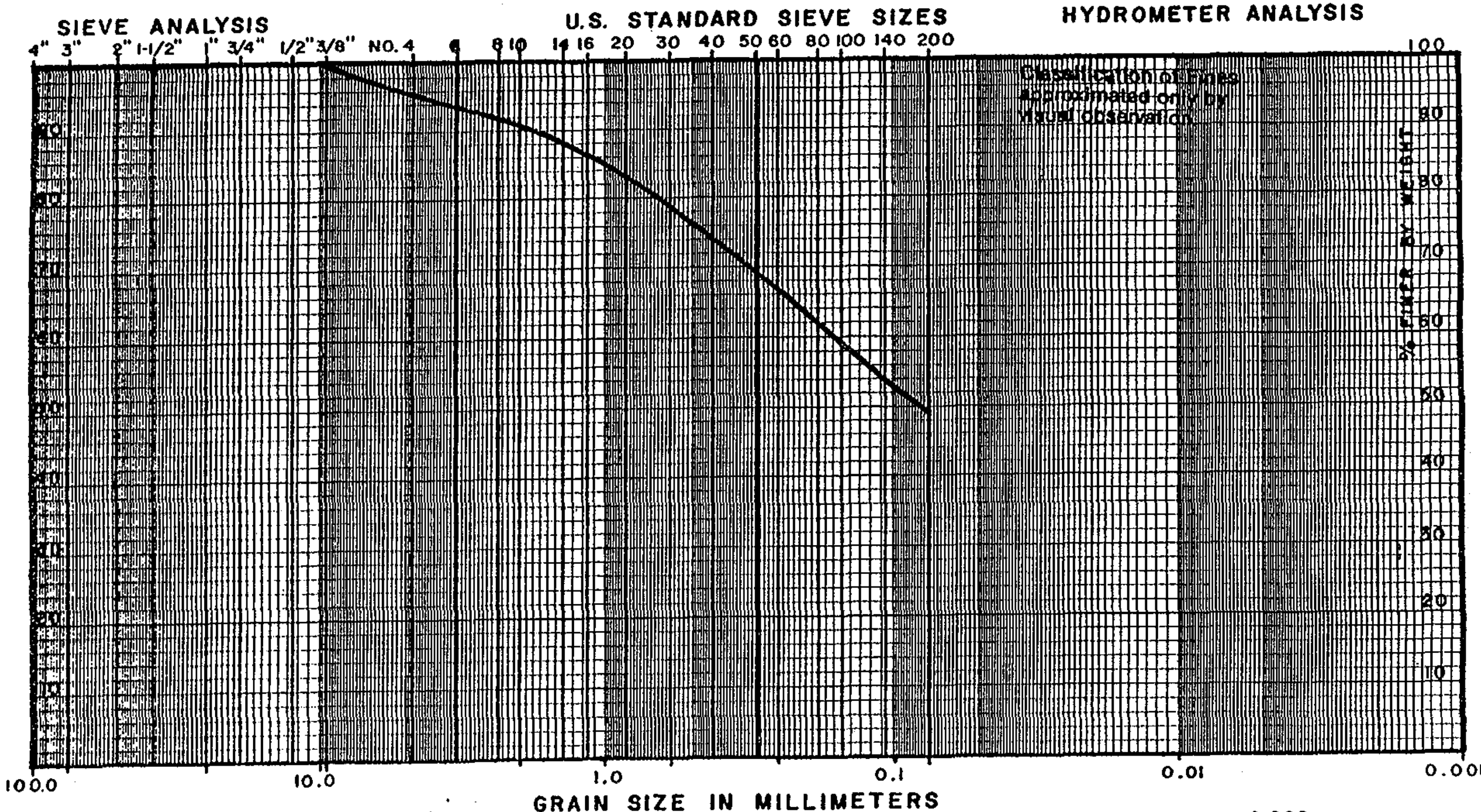
SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. ____

D-29



3"	1"	3/8"	2.0MM.	0.59	0.25	0.074	0.006

COBBLES	GRAVEL			SAND			SILT	CLAY
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE		

MECHANICAL ANALYSIS

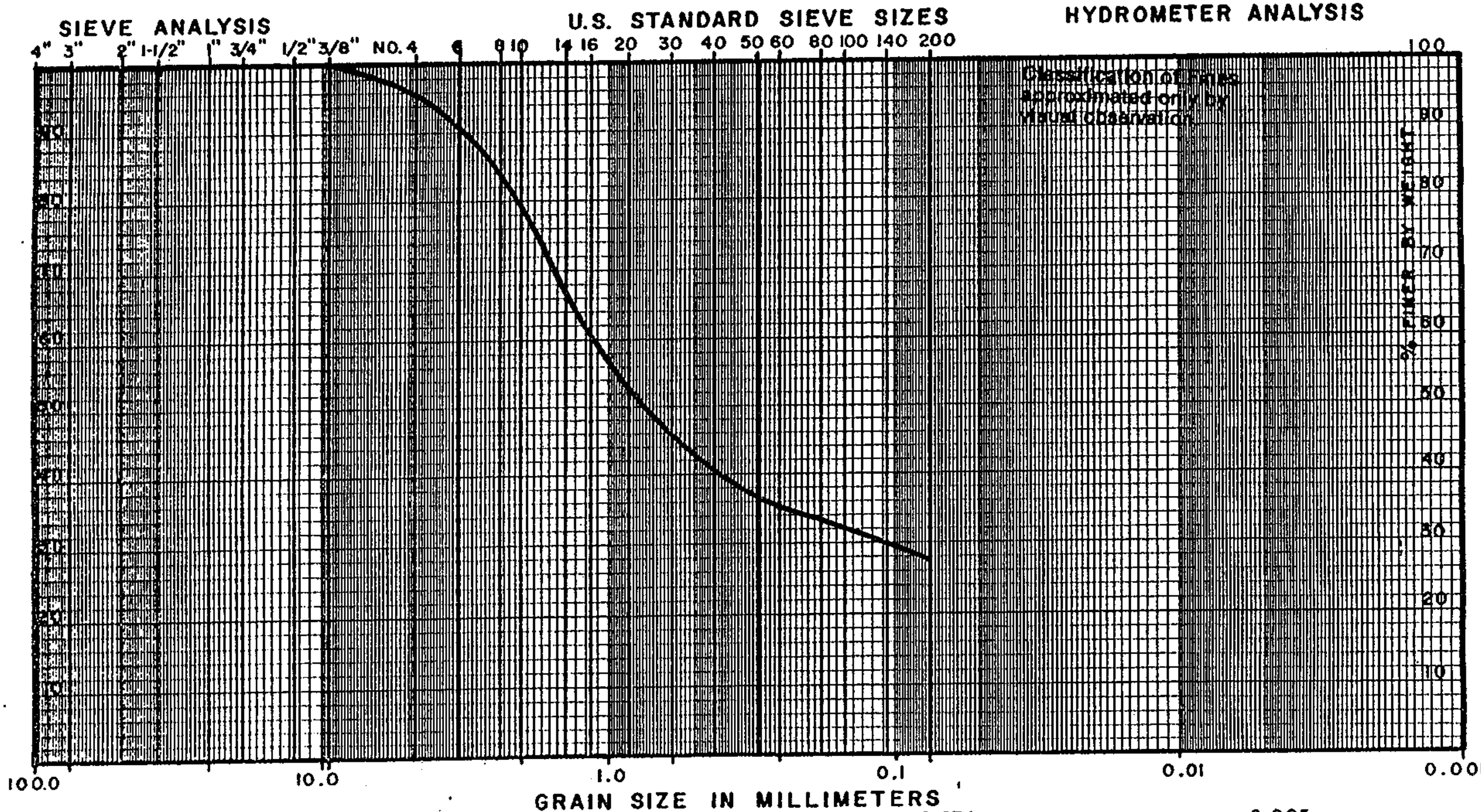
SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L %	P.L.%	P.I.
17174		Dark Grayish brown coarse to fine Sand, and (+) Silt, trace (+) fine Gravel. (DECOMP. WOOD, WOOD CHIPS, ROOTS & ODOR)				

SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 38



	3"		1"	3/8"	2.0MM.	0.59	0.25	0.074	0.005
COBBLES	COARSE	MEDIUM	FINE		COARSE	MEDIUM	FINE		
	GRAVEL				SAND			SILT	CLAY

MECHANICAL ANALYSIS

SAMPLE NO.	DEPTH	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
17175		Dark Gray coarse to fine SAND, some silt, some(-) fine Gravel. (DECOMPOSED WOOD, LEAVES, & ODOR)				

SS SHIMEL and SOR TESTING LABORATORIES, INC.

CLIENT: U.S. ARMY CORPS OF ENGINEER

PROJECT: MUDDY RIVER

DATE: 9-3-92 FIGURE NO. 37

ATTACHMENT II

MUDDY RIVER

METHOD 8270: SEMI-VOLATILE ORGANICS (mg/kg)

PARAMETER		17214 S-3 SEDIMENT		17216 S-5 SEDIMENT		METHOD BLANK SEDIMENT
Aniline	<	0.40	<	0.42	<	0.22
Phenol	<	0.080	<	0.083	<	0.044
Bis(2-chloroethyl)ether	<	0.080	<	0.083	<	0.044
2-Chlorophenol	<	0.080	<	0.083	<	0.044
1,3-Dichlorobenzene	<	0.080	<	0.083	<	0.044
1,4-Dichlorobenzene	J	0.10	J	0.22	<	0.044
1,2-Dichlorobenzene	<	0.080	<	0.083	<	0.044
Benzyl alcohol	<	0.16	<	0.17	<	0.088
2-Methylphenol	J	0.096	<	0.083	<	0.044
Bis(2-chloroisopropyl)ether	<	0.080	<	0.083	<	0.044
4-Methylphenol	J	0.40	J	0.44	<	0.044
N-Nitroso-di-n-propylamine	<	0.080	<	0.083	<	0.044
Hexachloroethane	<	0.080	<	0.083	<	0.044
Nitrobenzene	<	0.080	<	0.083	<	0.044
Isophorone	<	0.080	<	0.083	<	0.044
2-Nitrophenol	<	0.080	<	0.083	<	0.044
2,4-Dimethylphenol	<	0.080	<	0.083	<	0.044
Benzoic acid	<	0.40	<	0.42	<	0.22
Bis(2-chloroethoxy)methane	<	0.080	<	0.083	<	0.044
2,4-Dichlorophenol	<	0.080	<	0.083	<	0.044
1,2,4-Trichlorobenzene	<	0.080	<	0.083	<	0.044
Napthalene		2.6	J	0.65	<	0.044
4-Chloroaniline	<	0.16	<	0.17	<	0.088
Hexachlorobutadiene	<	0.080	<	0.083	<	0.044
4-Chloro-3-methylphenol	<	0.16	<	0.17	<	0.088
2-Methylnapthalene		1.3	J	0.56	<	0.044
Hexachlorocyclopentadiene	<	0.080	<	0.083	<	0.044
2,4,6-Trichlorophenol	<	0.080	<	0.083	<	0.044
2,4,5-Trichlorophenol	<	0.080	<	0.083	<	0.044
2-Chloronaphthalene	<	0.080	<	0.083	<	0.044
2-Nitroaniline	<	0.40	<	0.42	<	0.22
Dimethylphthalate	<	0.080	<	0.083	<	0.044
Acenaphthylene	J	0.31	J	0.18	<	0.044
3-Nitroaniline	<	0.40	<	0.42	<	0.22
Acenaphthene		1.9		1.2	<	0.044
2,4-Dinitrophenol	<	0.40	<	0.42	<	0.22
4-Nitrophenol	<	0.40	<	0.42	<	0.22
Dibenzofuran		3.0		0.88	<	0.044
2,6-Dinitrotoluene	<	0.080	<	0.083	<	0.044
2,4-Dinitrotoluene	<	0.080	<	0.083	<	0.044
Diethylphthalate	J	0.10	J	0.091	<	0.044

MUDDY RIVER

METHOD 8270: SEMI-VOLATILE ORGANICS (mg/kg)

PARAMETER		17214 S-3 SEDIMENT		17216 S-5 SEDIMENT		METHOD BLANK SEDIMENT
4-Chlorophenyl-phenylether	<	0.080	<	0.083	<	0.044
Fluorene		2.4		1.7	<	0.044
4-Nitroaniline	<	0.40	<	0.42	<	0.22
4,6-Dinitro-2-methylphenol	<	0.40	<	0.42	<	0.22
N-Nitrosodiphenylamine	<	0.080	<	0.083	<	0.044
1,2-Diphenylhydrazine	<	0.080	<	0.083	<	0.044
4-Bromophenyl-phenylether	<	0.080	<	0.083	<	0.044
Hexachlorobenzene	<	0.080	<	0.083	<	0.044
Pentachlorophenol	<	0.40	<	0.42	<	0.22
Phenanthrene	U	22		9.6	<	0.044
Anthracene		6.5		2.3	<	0.044
Di-n-butylphthalate	J	0.51	J	0.29	<	0.044
Fluoranthene	U	25		10	<	0.044
Pyrene	U	65	U	32	<	0.044
Butylbenzylphthalate	<	0.080	J	0.51	<	0.044
3,3-Dichlorobenzidine	<	0.16	<	0.17	<	0.088
Benzo(a)anthracene	U	24		7.3	<	0.044
Bis(2ethylhexyl)phthalate		1.9		6.7	<	0.044
Chrysene	U	24		9.1	<	0.044
Di-n-octyl phthalate	<	0.080	<	0.083	<	0.044
Benzo(b)fluoranthene	U	17		5.4	<	0.044
Benzo(k)fluoranthene	U	18		5.6	<	0.044
Benzo(a)pyrene	U	16		5.5	<	0.044
Indeno(1,2,3-cd)pyrene	U	18		6.4	<	0.044
Dibenz(a,h)anthracene		3.8		1.0	<	0.044
Benzo(g,h,i)perylene		13		5.6	<	0.044
DILUTION FACTOR		0.080		0.083		0.044
SURROGATE STANDARD RECOVERY (%):						
Nitrobenzene-d5 (23-120)		85		93		80
2-Fluorobiphenyl (30-115)		66		72		65
4-terphenyl-d14 (18-137)		229		241		87
2-Fluorophenol (25-121)		99		100		103
Phenol-d6 (24-113)		118		120		121
2,4,6-Tribromophenol (19-122)		125		135		95

SAMPLE DATE:	6/25/92	6/25/92	
DATE EXTRACTED:	8/11/92	8/11/92	8/11/92
DATE ANALYZED:	9/3/92	9/3/92	9/1/92

J - Estimated value; analyte detected at < the Practical Quantitation Limit.
U - Above the upper calibration limit.

MUDDY RIVER

METHOD 8270: SEMI-VOLATILE ORGANICS (mg/kg)

PARAMETER		17171 S-11 SEDIMENT		17175 S-15 SEDIMENT		METHOD BLANK SEDIMENT
4-Chlorophenyl-phenylether	<	0.066	<	0.076	<	0.067
Fluorene		1.9		0.78	<	0.067
4-Nitroaniline	<	0.33	<	0.38	<	0.34
4,6-Dinitro-2-methylphenol	<	0.33	<	0.38	<	0.34
N-Nitrosodiphenylamine	<	0.066	<	0.076	<	0.067
1,2-Diphenylhydrazine	<	0.066	<	0.076	<	0.067
4-Bromophenyl-phenylether	<	0.066	<	0.076	<	0.067
Hexachlorobenzene	<	0.066	<	0.076	<	0.067
Pentachlorophenol	<	0.33	<	0.38	<	0.34
Phenanthrene		13		2.2	<	0.067
Anthracene		2.3		1.2	<	0.067
Di-n-butylphthalate	U	20	B	1.2		0.38
Fluoranthene		12		5.2	<	0.067
Pyrene	U	29		19	<	0.067
Butylbenzylphthalate	<	0.066	<	0.076	<	0.067
3,3-Dichlorobenzidine	<	0.13	<	0.15	<	0.13
Benzo(a)anthracene		6.3		4.3	<	0.067
Bis(2ethylhexyl)phthalate		7.7		1.8	<	0.067
Chrysene		7.2		4.9	<	0.067
Di-n-octyl phthalate	<	0.066	<	0.076	<	0.067
Benzo(b)fluoranthene		5.6		5.9	<	0.067
Benzo(k)fluoranthene		5.8		6.1	<	0.067
Benzo(a)pyrene		5.1		4.9	<	0.067
Indeno(1,2,3-cd)pyrene		4.1		7.0	<	0.067
Dibenz(a,h)anthracene		0.99		0.93	<	0.067
Benzo(g,h,i)perylene		5.6		6.7	<	0.067
DILUTION FACTOR		0.066		0.076		0.067

SURROGATE STANDARD RECOVERY (%):		17171 S-11	17175 S-15	METHOD BLANK
Nitrobenzene-d5	(23-120)	81	85	77
2-Fluorobiphenyl	(30-115)	68	86	85
4-terphenyl-d14	(18-137)	182	247	90
2-Fluorophenol	(25-121)	87	78	72
Phenol-d6	(24-113)	101	109	96
2,4,6-Tribromophenol	(19-122)	34	71	85

SAMPLE DATE:	6/23/92	6/23/92	
DATE EXTRACTED:	7/23/92	7/23/92	7/23/92
DATE ANALYZED:	7/28/92	7/28/92	7/27/92

J - Estimated value; analyte detected at < the Practical Quantitation Limit.
B - Analyte also detected in Method Blank.

MUDDY RIVER

METHOD 8270: SEMI-VOLATILE ORGANICS (mg/kg)

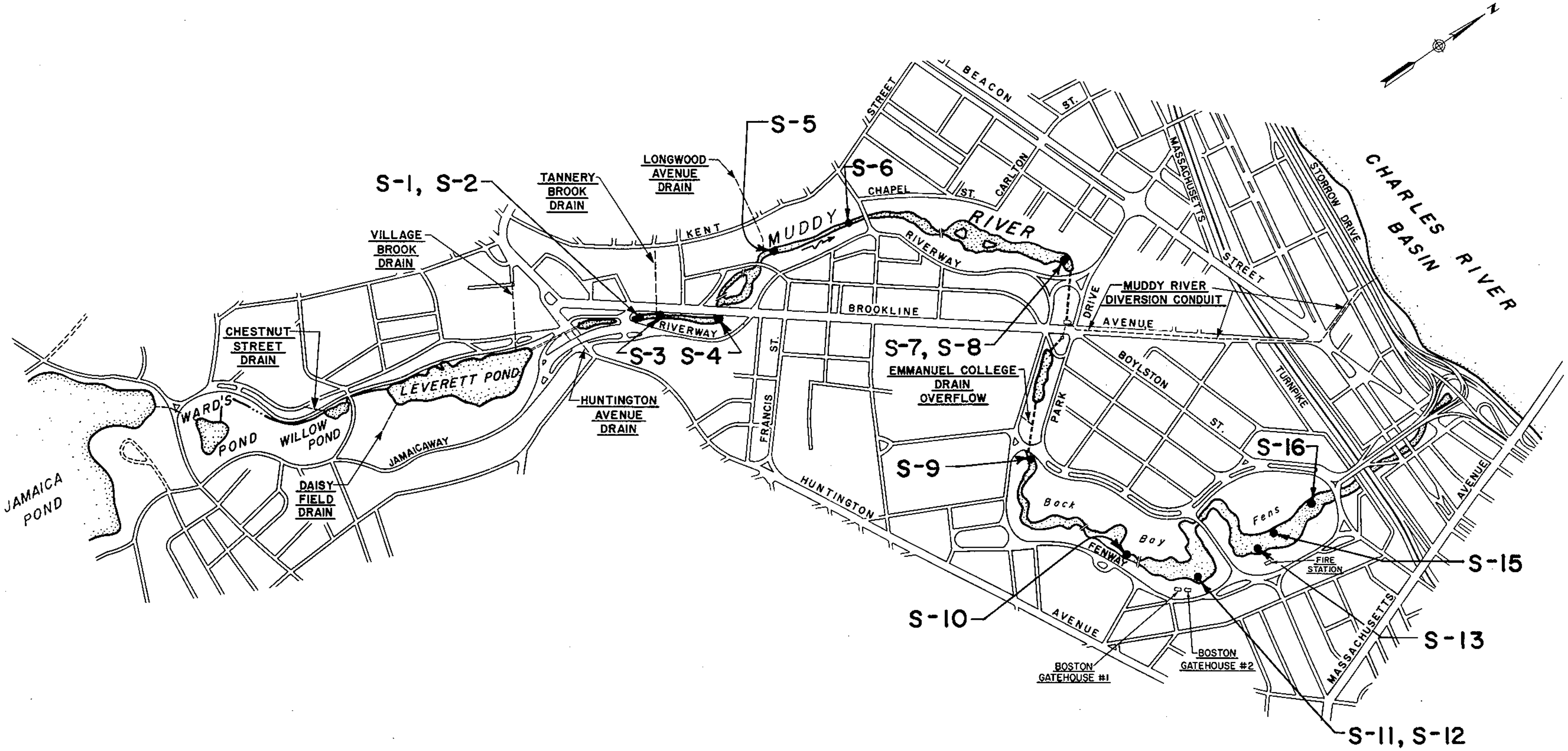
PARAMETER		17171 S-11 SEDIMENT		17175 S-15 SEDIMENT		METHOD BLANK SEDIMENT
Aniline	<	0.33	<	0.38	<	0.34
Phenol	<	0.066	<	0.076	<	0.067
Bis(2-chloroethyl)ether	<	0.066	<	0.076	<	0.067
2-Chlorophenol	<	0.066	<	0.076	<	0.067
1,3-Dichlorobenzene	<	0.066	<	0.076	<	0.067
1,4-Dichlorobenzene	J	0.32	<	0.076	<	0.067
1,2-Dichlorobenzene	J	0.25	J	0.23	<	0.067
Benzyl alcohol	<	0.13	<	0.15	<	0.13
2-Methylphenol	<	0.066	<	0.076	<	0.067
Bis(2-chloroisopropyl)ether	<	0.066	<	0.076	<	0.067
4-Methylphenol	<	0.066	<	0.076	<	0.067
N-Nitroso-di-n-propylamine	<	0.066	<	0.076	<	0.067
Hexachloroethane	<	0.066	<	0.076	<	0.067
Nitrobenzene	<	0.066	<	0.076	<	0.067
Isophorone	<	0.066	<	0.076	<	0.067
2-Nitrophenol	<	0.066	<	0.076	<	0.067
2,4-Dimethylphenol	<	0.066	<	0.076	<	0.067
Benzoic acid	<	0.33	<	0.38	<	0.34
Bis(2-chloroethoxy)methane	<	0.066	<	0.076	<	0.067
2,4-Dichlorophenol	<	0.066	<	0.076	<	0.067
1,2,4-Trichlorobenzene	<	0.066	<	0.076	<	0.067
Napthalene		1.6	J	0.54	<	0.067
4-Chloroaniline	<	0.13	<	0.15	<	0.13
Hexachlorobutadiene	<	0.066	<	0.076	<	0.067
4-Chloro-3-methylphenol	<	0.13	<	0.15	<	0.13
2-Methylnapthalene		1.1		0.35	<	0.067
Hexachlorocyclopentadiene	<	0.066	<	0.076	<	0.067
2,4,6-Trichlorophenol	<	0.066	<	0.076	<	0.067
2,4,5-Trichlorophenol	<	0.066	<	0.076	<	0.067
2-Chloronaphthalene	<	0.066	<	0.076	<	0.067
2-Nitroaniline	<	0.33	<	0.38	<	0.34
Dimethylphthalate	<	0.066	<	0.076	<	0.067
Acenaphthylene	J	0.19	J	0.42	<	0.067
3-Nitroaniline	<	0.33	<	0.38	<	0.34
Acenaphthene		1.4	J	0.34	<	0.067
2,4-Dinitrophenol	<	0.33	<	0.38	<	0.34
4-Nitrophenol	<	0.33	<	0.38	<	0.34
Dibenzofuran		1.4	J	0.48	<	0.067
2,6-Dinitrotoluene	<	0.066	<	0.076	<	0.067
2,4-Dinitrotoluene	<	0.066	<	0.076	<	0.067
Diethylphthalate	B,J	0.32	<	0.076	J	0.17

METHOD 8240: VOLATILE ORGANICS - SEDIMENT (ug/kg)

PARAMETER		17171 * S-11 SEDIMENT		17175 * S-15 SEDIMENT		17214 * S-3 SEDIMENT		17216 * S-5 SEDIMENT		METHOD BLANK SEDIMENT
Chloromethane	<	15	<	22	<	13	<	9.4	<	5.0
Vinyl chloride	<	15	<	22	<	13	<	9.4	<	5.0
Bromomethane	<	15	<	22	<	13	<	9.4	<	5.0
Chloroethane	<	15	<	22	<	13	<	9.4	<	5.0
1,1-Dichloroethene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Acetone		312	J	218	J	263	U	466	<	30
Carbon disulfide	J	6.0	J	8.6	<	5.3	J	5.1	<	2.0
Methylene chloride	B	57	B	105	B	49	B	41		12
trans-1,2-Dichloroethene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
1,1-Dichloroethane	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
cis-1,2-Dichloroethene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
2-Butanone		121	<	129	<	80	J	166	<	30
Chloroform	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
1,1,1-Trichloroethane	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Carbon tetrachloride	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Benzene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
1,2-Dichloroethane	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Trichloroethene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
1,2-Dichloropropane	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Bromodichloromethane	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
4-Methyl-2-pentanone	<	60	<	86	<	53	<	37	<	20
cis-1,3-Dichloropropene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Toluene	<	6.0	<	8.6	<	5.3	J	6.6	<	2.0
trans-1,3-Dichloropropene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
1,1,2-Trichloroethane	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Tetrachloroethene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
2-Hexanone	<	60	<	86	<	53	<	37	<	20
Dibromochloromethane	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Chlorobenzene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Ethylbenzene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
m/p Xylene	<	6.0	<	8.6	<	5.3		9.6	<	2.0
O-Xylene		14	<	8.6	<	5.3		13	<	2.0
Styrene	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Bromoform	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
1,1,2,2-Tetrachloroethane	<	6.0	<	8.6	<	5.3	<	3.7	<	2.0
Surrogate Recovery (%)										
1,2-Dichloroethane D4 (70-121)		82		88		83		83		80
Toluene D8 (84-138)		109		125		117		143		103
4-Bromofluorobenzene (59-113)		92		80		80		106		100
DILUTION FACTOR		3.0		4.3		2.7		1.9		1.0

	17171	17175	17214	17216	METHOD BLANK
SAMPLE DATE:	6/23/92	6/23/92	6/25/92	6/25/92	
DATE ANALYZED:	7/16/92	7/16/92	7/16/92	7/16/92	7/16/92

J - Estimated value; analyte detected at < the Practical Quantitation Limit.
B - Analyte also detected in Method Blank.
* - Probably petrogenic peaks present.



NOTES:
ALL SAMPLES WERE CORES TAKEN TO A DEPTH OF ABOUT 2 FEET.
SAMPLES S-2, S-8, S-12 AND S-15 WERE TAKEN WITHIN PHRAGMITES STANDS.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER RECONNAISSANCE STUDY

JUNE 1992-SEDIMENT SAMPLING STATIONS

PLATE D-1

APPENDIX E

ENVIRONMENTAL RESOURCES

APPENDIX E: ENVIRONMENTAL RESOURCES

TABLE OF CONTENTS

INTRODUCTION

This Appendix provides information about the Muddy River study area with a focus on biological resources. Also discussed are the environmental impacts of proposed flood control and water quality improvement projects.

Additional information about water quality, sedimentology, and Phragmites is presented in Appendices C, D, and F, respectively. Cultural resources are discussed in the Main Report.

GENERAL DESCRIPTION OF PROJECT AREA

The Muddy River is located within the communities of Boston, Brookline, and Newton in eastern Massachusetts (see Plates 1 and 2 in Main Report). The river originates at Jamaica Pond (a 68-acre spring fed kettle hole lake) and flows northward through a series of ponds (Willow, Wards, and Leverett Ponds), open channel, culverts, and pools before entering the Charles River about 3.7 miles downstream of its origin (see Plate 4 in Main Report). The river basin has a total drainage area of 8.6 square miles and is highly urbanized.

The Muddy River flows through a series of parks (Olmstead Park, the Riverway, and the Back Bay Fens) known as the "Emerald Necklace" designed by the famous 19th century landscape architect Fredrick Law Olmstead (see Main Report; Zaitzevsky, 1982). Olmstead Park includes Jamaica, Willow Wards, and Leverett Ponds and surrounding park land. The Riverway includes the Muddy River and adjacent park land between the Leverett Pond outlet and Park Drive. The Back Bay Fens include the Muddy River and surrounding park land from downstream of Park Drive to Boylston Street.

The river flows in a well defined channel in the Riverway for about 1.8 miles before entering the "Back Bay Fens" (see Plate 4). The river ranges in width from about 10-20 feet downstream of the Leverett Pond discharge to 150 to 200 feet near Park Drive. Water depth generally ranges from 2 to 4 feet. Flow is generally sluggish. The reach has been dredged periodically in the past, the last time in 1963. The upper reach of between Huntington Street and River Road is channelized with stone slope protection. The Riverway itself ranges in width from about 100 to 600 feet and is bordered by heavily developed areas.

The Back Bay Fens section of the Muddy River flows through a series of shallow basins for about 1.5 miles before entering the Charles River Basin through an underwater culvert. Total surface water area in the Fens is about 17 acres. Existing water depth ranges from about 1 to 6 feet. Extensive organic-rich sediment deposits are present throughout much of the Back Bay Fens. The deposits range in depth from about 6 inches to 12 feet, with an average depth of about 5-6 feet (MDWPC, 1973). Several hundred feet of the river immediately downstream of Park Drive (the Sears parking lot) and upstream of Louis Pasteur avenue passes through closed culverts. The lower reach of the river between Bolyston Street and the Charles River Basin outlet is channelized.

Muddy River water quality is currently extremely poor (see Appendix C). Major problems identified include high fecal coliform levels, low dissolved oxygen levels, and high nutrient levels and associated algal blooms. In addition, sediments are heavily contaminated with metals, polycyclic aromatic hydrocarbons, and petroleum hydrocarbons (see Appendix D).

BIOLOGICAL RESOURCES

Aquatic Biota

Invertebrates

Aquatic invertebrate communities in the Muddy River and Back Bay Fens are depauperate and composed largely of taxa tolerant of poor water quality conditions (MDC, 1982). Species noted in the Back Bay Fens in previous studies include aquatic oligocheate worms (Tubifex tubifex and Limnodrilus hoffmeister), chironomid larvae, snails, water striders (Gerridae), and crayfish. Tubifex and Limnodrilus are typically of highly organic, oxygen deficient sediments. Invertebrates noted in the Muddy River include oligochaetes, midges (Pentaneurini, Endochiromous), scuds (Amphipoda), chironomids (Psectrocladus), fingernail clams (Sphaeriidae), crayfish (Astocidae), nematodes, and snails.

Fish

The Muddy River currently supports a limited warmwater fishery due to poor water and habitat quality. Carp, a species tolerant of very poor water quality conditions, is predominant in both the Back Bay Fens and Riverway. Large Carp were frequently seen near bridges in the both the Fens and Riverway during this study. Other species known to occur in the river include brown bullhead, goldfish, golden shiner, sunfish, largemouth bass, and American eel (Maietta, 1991).

Fish sampled from the Muddy River and Back Bay Fens in 1990 contained high levels of PCBs (Maietta, 1991). Seven of the 14 fish analyzed had PCB levels which met or exceeded the USDA action level of 2 ppm (maximum concentration was 3.4 ppm). Carp with high tissue lipid content had the highest PCB levels. Based on this information, a public health advisory was issued recommending people not consume carp, brown bullhead, or American eel from the Muddy River and limit consumption of other species to two meals per month. Concentrations of metals in fish were low, and did not exceed FDA action levels.

Jamaica Pond supports a good warmwater fishery, with healthy populations of large mouth bass, yellow perch, bluegill, pumpkinseed, white crappie, pickerel, and bullhead (Leahy, 1989). The lake is also stocked on a put and take basis with rainbow trout, and sometimes brown and brook trout.

The Muddy River and Fens has the potential to support a good warmwater fishery, provided that habitat quality were improved and the PCB problem eliminated through dredging or other measures. Populations of largemouth bass, yellow perch, sunfish, white catfish, and possibly herring could be established through stocking (Bergin, 1986). Establishing a herring run might require some structural modifications to provide for fish passage at the mouth of the river.

Algae

Extensive mats of filamentous algae are present in the the Back Bay fens during summer months. Those observed during this study were formed by blue green algae (cf. Oscilatoria). The mats develop on sediments in shallow water areas and float to the surface due to decomposition gasses. The mats are unsightly, produce noxious odors upon decomposition, and limit recreational use of the water.

Corps water quality sampling found moderately high counts of planktonic algae (primarily diatoms and greens) in both the Riverway and Back Bay Fens in June of 1992, but low levels by August (see Appendix C).

Wetland Vegetation

Extensive Phragmites stands are present in the Riverway and the Back Bay Fens (see Appendix F). In the Riverway, Phragmites currently occupy about 2 acres, and grow along 30 percent of the shoreline. In the fens, Phragmites development is most extensive in the Northern and Southern Basins where a total of 3.3 acres is present. Phragmites occur along about 90 percent of the Northern Basin shoreline and 50 percent of the Southern Basin shoreline. Phragmites growth in the Muddy River is robust. In well established stands shoots frequently exceed 5 meters in height, and range up to nearly 7 m. In shallow water stands are expanding laterally several meters per year. Phragmites aboveground live standing crop near Park Drive in October, 1992 was about 4,000 g/m^2 (dry weight), well above values typically reported for the species in North America.

A few small cattail stands are also present in the Muddy River. The largest of these are in the Riverway (near Park Drive), and in the Upper and Lower Fens Basins near the Agassiz Bridge.

A narrow fringe of emergent vegetation occurs along shore throughout the Riverway and Back Bay fens in locations that are not colonized by Phragmites or heavily shaded by riparian vegetation. Common species present include purple loosestrife, sedges, smartweed, beggars-ticks, Iris, pickerelweed, sweet fern, and aquatic grasses.

A few freshwater herbaceous wetland plants were included in Olmstead's original plantings in the Muddy River (Zaitzevsky, 1982). These include sweet flag, Cinnamon fern, sweet fern, and marsh marigold. Three of the most common emergents in the Muddy River today, Phragmites, cattails, and loosestrife, were apparently not planted. Various saltmarsh grasses were planted in the fens by Olmstead, but are no longer present, presumably due to filling in the early 1900's and elimination of tidal tidal flushing by the Charles River Dam in 1919.

Riparian and Terrestrial Vegetation

Plant communities along the Muddy River originate from plantings made in the 1890's during construction of the Emerald Necklace parks. Plans called for planting a great variety of trees, shrubs, and herbaceous species (see Zaitzevsky, 1982). Although a thorough inventory of present vegetation is not available, over the years much of the intended diversity has apparently been lost (Massachusetts DEM, undated).

Riparian vegetation is currently well developed along much of the Riverway section of the Muddy River and the Upper Fens Pond. In the Riverway, tree and shrub cover is heavy along most of the Brookline side of the river from the Leverett Pond outlet to Park Drive. Vegetation is less well developed along much of the Boston side of the river, where lawn is maintained nearly to the river's edge. A list of common species noted along the Riverway is presented in Table E-1. Mature oaks and maples are most common in the overstory. The most common shrubs and small trees are European buckthorn, arrowwood, Japanese barberry, honeysuckles, and river birch. Japanese knotweed, an invasive non-native herbaceous species, is abundant at several locations.

Oaks and sugar maple are most common near the inlet and outlet of the Upper Fens Pond. Box elder weeping willow, cherry, and European buckthorn are also present.

Riparian vegetation is much less well developed along the Back Bay Fens section of the Muddy River downstream of the Upper Fens Pond. Shoreline vegetation is limited to shrubs and scattered trees. European buckthorn, birch, and weeping willow are common. Turf extends to the shoreline (or edge of Phragmites) in most locations. Away from the river, most of the Back Bay Fen park land is turf.

Wildlife

The Muddy River and associated riparian vegetation, marshes, and park land provide habitat for a great variety of mammals, birds, and reptiles (Leahy, 1989). The area supports resident (breeding) populations of many species and provides a refuge for songbirds and waterfowl migrating through the Boston area.

A list of birds likely to nest or commonly occur in the Riverway and/or Back Bay Fens is presented in Table E-2. Many other species have been reported from the area over the last several decades, and may still occasionally occur as transients (see Leahy, 1992 for a more complete list). Semi-domesticated mallards are very abundant in both the Riverway and Back Bay Fens throughout the year.

Mammals known or likely to occur in the project area include gray squirrel, raccoon, striped skunk, opossum, muskrat, Norway rat, big brown bat, mice, voles, and shrews. Numerous rats where seen within Phragmites stands during this study.

Reptiles and Amphibians reported to occur in the project area include painted turtle, snapping turtle, bull frog, red eared turtle (Hudson, 1991b), and American toad. Others reported from the Olmstead Park area which may also occur in the Riverway or Fenway include spotted turtle, stinkpot turtle, eastern garter snake, DeKay' snake, red-backed salamander, dusky salamander, green frog, and leopard frog.

Threatened and Endangered Species

No federally listed threatened or endangered species are known to occur in the project area (Lauber, 1992). A rare fish, the threespine stickleback (Gasterosteus aculeatus), is known to occur in a small spring-fed pool which drains into Willow Pond. The species is state-listed as threatened, and the population is the only one known to occur in Massachusetts. Spotted turtle, a state listed special concern species is known to occur in the Olmstead Park area.

Table E-1:
Trees and Shrubs Noted Growing Along the Riverway Section of the Muddy River.

Black Cherry	Red-panicled Dogwood
Red Oak	Sumac
Scarlet Oak	Hawthorne
Black Oak	Japanese Barberry
Chestnut Oak	Oriental Bittersweet
Elm	European Buckthorn
Box Elder	Sweet Pepperbush
Weeping Willow	Dogwood
Red Maple	Northern Arrowwood
Sugar Maple	Honeysuckles
River Birch	Common Elderberry
White Birch	Grey Birch

Table E-2:
Birds Likely to Occur in the Muddy River Project Area.

Resident Land Birds

American kestrel
red tailed hawk
wastern screech owl
chimney swift
northern flicker
downy woodpecker
eastern phoebe
tree swallow
barn swallow
blue jay
rock dove (pigeon)
American crow
tufted titmouse
black-capped chickadee
white breasted nuthatch
house wren
American robin
gray catbird
northern mockingbird
warbling viero
black and white warbler
American redstart
yellow warbler
cardinal
song sparrow
chipping sparrow
swamp sparrow
white throated sparrow
common grackle
brown-headed cowbird
red-winged blackbird
northern oriole
orchard oriole
American goldfinch

Wading and Shorebirds

great blue heron
green heron
black-crowned night heron
snowy egret
solitary sandpiper
spotted sandpiper
semipalmated sandpiper
killdeer
sora
dowitcher sp.
yellowlegs sp.

Waterfowl

mallard
black duck
American coot
common merganser
Canada goose
green-winged teal
cormorant
red-eyed viero

Others

herring gull

Based on Leahy (1989) and observations by Hudson (1991a and 1991b).

ENVIRONMENTAL IMPACTS

Flood Control Alternative I (Option A)

This option would replace the twin 6 foot culverts upstream of Brookline Avenue Gatehouse with a 535 foot long 10 x 20 foot box culvert. The twin 6 foot culverts upstream of Louis Pasteur Avenue would be replaced with an open channel excavated to -4.0 NGVD. The channel would have a bottom width of 30 feet, side slopes no steeper than 1 on 2, a length of about 400 feet, and a surface area of about 0.4 acres. In addition, the Muddy River would be dredged from the outlet of the culverts under Brookline Avenue to the Bolyston Street Bridge. The channel would be dredged to -4.0 NGVD, have a bottom width of 30 feet, and side slopes no steeper than 1 on 2. Approximately 5-6 acres would be dredged, and 22,000 cubic yards of sediment removed from the river.

Aquatic Resources

Replacement of the culverts upstream of Louis Pasteur Avenue with an open channel would restore about 0.4 acres of aquatic habitat. The channel would be situated in approximately the same location as the original Muddy River channel that was filled in the early 1940s.

The restored channel would quickly be colonized by aquatic invertebrates, fish, and other aquatic life. Habitat value of the channel would be low, however, without significant improvement in Muddy River water quality. Bottom sediment quality in the new channel might be poor if original Muddy River sediments were heavily contaminated. Additional testing would be needed to determine sediment quality in the new channel. If sediments in the new channel were found to be heavily contaminated, it might be desirable to excavate the channel to below final grade and backfill with clean fill.

Replacement of the Brookline Avenue gatehouse culverts could be done with minimal impacts on aquatic resources. Muddy River flow would continue through the existing culvert and Muddy River conduit while the new box culvert was constructed.

Removal of the culverts upstream of Louis Pasteur Avenue would probably require diversion of the Muddy River through the Muddy River Conduit and dewatering of the Upper Fens Pond for several months. Most aquatic life in the pond would be lost, but the area would be quickly recolonized after completion of the project. Water level in the river downstream of the Louis Agassiz Bridge is controlled by the Charles River Dam and would not be affected by the diversion.

Dredging would temporarily increase levels of suspended sediments, nutrients, and metals in the water, and decrease dissolved oxygen concentration. The extent of water quality impacts would depend largely on the equipment used. Hydraulic dredging would likely have minor, localized water quality impacts. Mechanical dredging, however, would probably have severe short-term water quality impacts. Dissolved oxygen and contaminant levels would likely violate criteria established to protect aquatic life.

Dredging solely for flood control would probably improve Back Bay Fens water quality only slightly. Some improvement might occur since filamentous algal blooms would not occur in the dredged channel due to low light availability. Extensive shallow, nutrient rich, sediments would remain in the Fens, however, and blooms would continue in these areas unless much more extensive dredging was conducted.

Dredging would destroy existing invertebrate communities and displace fish occurring in the project area. Mechanical dredging would probably kill some fish through exposure to high suspended sediment levels. Fish eggs and larvae would be especially vulnerable, and it is likely that most individuals of the current year-class would be lost. Hydraulic dredging would greatly reduce fisheries impacts.

Aquatic invertebrates and fish would quickly recolonize dredged areas. Sediments in the new channel would likely be similar to existing sediments and support a similar invertebrate community. Fish community composition would not appreciably change unless much more extensive dredging was conducted to improve habitat. Dredging or other modifications would have no impact on the three-spined stickleback population, which occurs in the Muddy River well upstream of the work area.

Although most of the 5 to 6 acres that would be dredged for the flood control channel is currently open water, several thousand square feet of existing emergent wetland vegetation would be dredged. Phragmites would be dredged near Louis Pasteur Avenue, near the Aggasiz Bridge, and in the Northern Basin. A few thousand square feet of cattail growing in the Southern Basin and other emergent vegetation occurring where channel width is less than about 35 feet would also be dredged. Increased water depth would prevent emergent plants from recolonizing dredged areas. Maintaining the channel would assure that some open water in the Fens is protected from future Phragmites expansion.

Terrestrial Resources

Replacement of the Brookline Avenue Gatehouse culvert would require clearing a few large trees from the Sears parking lot. Additional vegetation would be cleared from the riverbank near the existing outlet. Disturbed areas would be replanted with trees and shrubs. Several thousand square feet of turf would be disturbed, but would be restored after completion of the project.

Restoring the Muddy River channel upstream of the Louis Pasteur Bridge would eliminate about 0.5 acre of existing turf. About 20 large trees growing near existing culvert inlet would be lost. Turf would be replaced with about 0.4 acres of riparian habitat along side slopes. Side slopes would be landscaped with trees and shrubs, possibly similar to those specified by Olmstead in the original Muddy River planting plans.

A staging area would be required near the river for equipment storage and dewatering dredged material. Location has not been determined, but a few acres would probably be required. The area would be restored following completion of the work.

Dredging would likely destroy some shallow water or mudflat habitat used by wading birds and turtles. It might be possible to mitigate for this impact by creating some mudflat elsewhere in the fens.

__Socio-economic Resources__

Work on the Brookline Avenue culverts would disrupt traffic and reduce available parking in the area for several months (the lot has space for about 175 cars). Parking is already limited in the area, and this could impose a hardship on local businesses and the public. Recreational use and enjoyment of the area would be disrupted by construction equipment and noise.

Connecting the Upper Fens Pond with the Muddy River below the Louis Pasteur Bridge would improve aesthetics in the area and help restore Olmstead's vision of the park. Loss of turf situated upstream of the bridge would not significantly impact on recreation since it appears little used, and substantial other open-space is present in the area.

Dredging activities would distract from recreational use of the area for several months. The necessary hydraulic lines and dewatering facilities would be unsightly. Truck traffic to dispose of dewatered dredged material would exacerbate traffic problems in the area.

__Flood Control Alternative I (Option B)__

This option is similar to Option A, except that the Brookline Avenue culverts would be replaced with an open channel instead of a box culvert. Impacts associated with this alternative are very similar to those for Option A. This alternative would provide a partial link between the Riverway and Back Bay Fens, and would create an additional 0.4 acres of riverine and riparian habitat. Perhaps the greatest benefit would be improved aesthetics and reestablishment of a nearly unbroken pedestrian walkway along the river. The channel would also enhance wildlife movement between the the Riverway and Fens to some extent, though wildlife transiting the area would still need to negotiate two busy highways. These benefits would be at the expense of about 175 parking spaces currently available at the Sears parking lot. More detailed studies would be needed to ascertain the impact of the lost parking.

Flood Control Alternative II

This alternative involves solely replacing culverts upstream of the Brookline Avenue gatehouse with either a box culvert or open channel. Culverts upstream of the Louis Pasteur Bridge would not be removed, and the channel would not be improved by dredging.

The impacts of this alternative are identical to those discussed above for work on the Brookline Avenue culvert. Major adverse impacts include traffic problems, lost parking, and disruption of recreational activities. Impacts to aquatic life would be minimal. As above, an open channel has advantages over a box culvert since it would restore some riparian/aquatic habitat and improve recreational access between the Riverway and Back Bay Fens.

Water Quality Improvement Alternatives

Muddy River water quality is currently extremely poor. Major problems identified include high fecal coliform levels, low dissolved oxygen levels, high nutrient levels, and algal blooms. In addition, sediments are heavily contaminated with metals, polycyclic aromatic hydrocarbons, and petroleum hydrocarbons. Hydrogen sulfide released from anaerobic bottom sediments and decaying algae regularly poses an odor problem which detracts from recreational use of the area. The existing fishery is limited largely to pollution tolerant species such as carp and bullhead, and fish have high PCB levels.

Corps authority to participate in water resource projects in the Muddy River is currently limited to flood control. As part of this study, however, several proposed measures to improve Muddy River water quality were evaluated (see Appendix C). The major impacts associated with each of these alternatives are discussed below.

Source Control

Source control measures (e.g. elimination of sewer cross connections, construction of catch basins, street sweeping) are essential to reduce further nutrient and contaminant loading into the river. Although implementation of these measures would improve water quality to some extent, major problems would still remain. Existing organic and nutrient rich sediments would continue to exert a high oxygen demand and release nutrients (particularly phosphorous) into surface waters. Summer algal blooms would likely continue. Subsequent decomposition of algal biomass would continue to cause low dissolved oxygen levels and release of hydrogen sulfide gas.

High levels of metals and other contaminants would remain in sediments, and continue to exceed levels likely to adversely affect aquatic life. Petroleum hydrocarbon levels and PCB levels would decline due to natural bacterial degradation. In time, lower PCB levels in sediments would result in lower levels in fish.

In-stream Treatment/Aeration

In conjunction with source control, installing in-stream water treatment and/or aeration facilities could improve Muddy River water quality to some extent by maintaining higher DO levels in the Riverway and Back Bay Fens throughout the critical summer low flow period. In-stream treatment could also improve water quality by filtering suspended matter and nutrients from the water. Studies of sediment oxygen demand and a water quality model would be needed to further evaluate the practicality of this alternative.

Maintaining higher DO levels would reduce release of phosphorus, metals, and hydrogen sulfide from sediments. Assuming that effective source controls were in place to control nutrient loading, the severity of algal blooms could probably be reduced and conditions for aquatic life generally improved. Complete elimination of blooms in the Back Bay Fens seems unlikely, however, given the existing shallow water conditions and nutrient rich sediments.

As was the case for "Source Control", high levels of contaminants would remain in river sediments and continue to pose a threat to aquatic life.

Operation of filtration or aeration systems would have minimal environmental impacts. Some land would be required for the necessary facilities. Care would be needed to site facilities so that adverse effects on historic resources and aesthetics were avoided.

Flow Augmentation

In conjunction with of source control, flow augmentation during low flow periods could also somewhat improve Muddy River water quality. As was the case for filtration/aeration, the primary benefit would be higher DO levels. As above, studies of sediment oxygen demand and a water quality model would be needed to further evaluate the practicality of this alternative.

Maintaining higher dissolved oxygen levels would reduce release of phosphorus, metals, and hydrogen sulfide from sediments. Assuming that effective source controls were in place to control nutrient loading, the severity of algal blooms could be reduced. High levels of contaminants would remain in river sediments and continue to pose a threat to aquatic life.

Flow augmentation could have a number of adverse impacts. Flow diversion through the Muddy River conduit could carry contaminants discharged into the conduit into the Muddy River. Existing sediments in the conduit are highly contaminated (see Appendix D) and would need to be removed before the conduit could be used for augmentation. This would be a complicated and expensive undertaking. Flow augmentation rates high enough to significantly improve Back Bay Fens water quality might increase bank erosion in some locations, particularly upstream of the Duck Pond.

Use of well water to augment Riverway flow could lower groundwater levels, and adversely effect the condition of wooden pilings in the area. Impacts on groundwater level would likely be greatest in dry years when flow augmentation was needed the most. Augmentation using well water would require a well house, pump, and discharge structure. Care would be needed to site facilities so that adverse effects on historic resources and aesthetics were avoided.

Use of municipal water to augment flow would avoid potential groundwater impacts and could likely be accomplished without any new aboveground structures. Use of this option might be limited, however, during dry years when MDC reservoir levels were low.

Environmental Dredging and Phragmites Removal

By 1973 about 150,000 cubic feet of organic rich sediments had accumulated in the Back Bay fens (MDWPC, 1973). The material ranged in depth from about 6 inches to 12 feet, with an average depth of about 5-6 feet. Deepest deposits were located in the Southern Basin. Somewhat greater quantities may be currently present due to continued sedimentation over the last 20 years. High oxygen demand and nutrients released by the sediment is probably the principle cause of poor water quality in the Fens. In shallow areas, the sediments also provide a substrate for growth of filamentous algal mats, which eventually break free, decompose, and further degrade water quality.

Removing all or most of the accumulated sediments from the Back Bay Fens would improve water quality by reducing sediment oxygen demand, nutrient availability, and growth of algal mats. Extent of improvement is difficult to predict, and would depend largely on the amount of dredging done, composition of resulting bottom sediments, and effectiveness of source controls to limit further nutrient loading. Although no information about composition of underlying sediments is available, these sediments probably have lower nutrient levels and oxygen demand than existing surficial sediments. Contaminant levels may also to be lower. Further sediment testing would be needed to confirm this, however, and determine exactly how much dredging would be required to adequately improve water and sediment quality. If high contaminant levels were found in underlying sediments, capping with clean fill after limited dredging might be desirable.

Increasing water depth to 6 feet or more should be sufficient to prevent development of algal mats. Blooms of free floating algae could still, occur, however, if nutrient levels remained high. Elimination of the floating algal mats and odors produced by decaying vegetation would greatly improve the aesthetics of the area. Deepening the Fens would also improve fish habitat and allow for boating.

Dredging sediments from the Riverway would also be beneficial. As in Back Bay Fens, the accumulated sediments have a high oxygen demand which contributes to low dissolved oxygen levels in the water. Restoring channel depth would improve fish habitat. More sediment testing would be required to determine if dredging would substantial improve sediment quality.

A major environmental dredging project in the Muddy River would also likely involve removal of about 5.3 acres of Phragmites from the Back Bay Fens and Riverway (see Appendix F). An additional several thousand square feet of cattail and other emergent vegetation would also be dredged.

Removal of the Phragmites would greatly improve aesthetics of the area and improve public safety, but result in loss of some wildlife habitat value (chiefly cover value). Lost wildlife habitat value could be adequately mitigated by planting cattail or other less obtrusive emergent species in suitable areas.

Phragmites stands in the Riverway probably improve Muddy River water quality by enhancing settling of suspended sediments and providing a substrate for organisms which remove dissolved nutrients from the water. Loss of Phragmites in the Riverway without implementation source control measures could significantly degrade downstream water quality. Even with source control, it would be desirable to plant cattail in some locations along the Muddy River to promote continued biolfiltration of Muddy River water before it enters the Back Bay Fens.

Mudflat habitat utilized by shorebirds would also be lost due to dredging. Measures to protect some existing habitat or mitigate for losses by creating new habitat would be desirable.

Adverse short-term dredging impacts were discussed in detail above for Flood Control Alternative I. These include water quality degradation, loss of aquatic life, increased truck traffic, disruption of recreational use of the area, and poor aesthetics. All of these impacts are temporary, and would be outweighed by the long-term benefits of improved water quality and Phragmites removal.

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APPENDIX F

Phragmites

APPENDIX F: PHRAGMITES

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PHRAGMITES LIFE HISTORY

Phragmites australis is a common grass in freshwater and slightly brackish marshes throughout the world (see Marks 1986 and references therein). The plant consists of perennial underground stems (rhizomes) and aboveground shoots bearing leaves and flowers. In established stands, aboveground shoots arise each spring from buds attached to the rhizomes. Growth is rapid, as the young shoots draw upon energy reserves stored in the rhizomes during the previous growing season. Shoots typically grow 2 to 4 meters tall by late summer, but may reach 6-7 meters in unusually productive stands. Shoots typically flower between July and September. New rhizomes develop from summer through fall. Stands can spread up to several meters per year through growth of the rhizomes. Shoots can grow in water up to about 3 feet deep, but have low tolerance for wave or current action. In standing water, rhizomes are typically within 2 feet of the substrate surface. Phragmites is frequently found growing on embankments or in other seemingly "upland" areas sicne rhizomes can grow up to six feet down to reach shallow groundwater.

RIVERWAY SECTION OF THE MUDDY RIVER

Past and Current Conditions

Aerial photos indicate that little or no Phragmites was present in this section of the Muddy River in 1966 (three years after it was last dredged). By 1977, 12 distinct stands with a total area of about 0.75 acres were present. The largest stands were near Park Drive, downstream of Brookline Avenue, and downstream of Longwood Avenue. Since 1977, both the number and size of stands has increased. Phragmites currently occur along about 30 percent of the river shoreline and occupy about 2 acres (or 20 percent) of the river surface (Plate F-1). Seventeen distinct stands, ranging in size from about 100 square feet to 0.60 acre are present. Growth is most extensive upstream of Park Drive, near Brookline Avenue, and downstream of Route 9. Most of the largest stands (i.e > 2,000 square feet) currently present were well established by 1977. A large stand present downstream of Longwood Avenue in 1977 no longer exists, presumably due to control efforts by the Boston Parks and recreation Department (no information about how the stand was eradicated is available).

Stands extends along both banks of the river for about 600 feet upstream of the Park Drive culverts. Phragmites cover in this area has expanded from about 0.3 acres in 1977 to 1.0 acres in 1992. Although substantial open water is still present along the reach, Phragmites extend nearly across the entire river at some locations. As is the case elsewhere in the river, Phragmites distribution appears to be limited to areas where water depth is about 3 ft. or less.

A second large stand is present downstream of Brookline Avenue, adjacent to the Riverwalk Island (Plate F-2). The stand has colonized the entire eastern channel of the river. Phragmites cover has expanded from a few thousand square feet in 1977 to about 0.5 acre in 1992. Maximum water depth in the channel has decreased from about 6 feet after dredging in 1963, to about 2 feet in 1992. The channel along the western side of the island is free of Phragmites, presumably due to steep embankments and heavy shading by riparian vegetation.

Phragmites growth in the Muddy River is robust. In well established stands, shoots frequently exceed 5 meters in height, and range up to nearly 7 m. In shallow water, where space is available, stands are typically expanding laterally several meters per year. Phragmites aboveground live standing crop near Park Drive in October, 1992 was about 4,000 g/m^2 (dry weight), well above values typically reported for the species in North America.

Phragmites obscures views of the Muddy River and is generally regarded to detract from the aesthetics of the area. On the positive side, the stands have some cover value for wildlife (see Appendix E) and probably help to improve Muddy River water quality before it passes into the Back Bay Fens. Phragmites shoots and litter (dead stems and leaves) provide a substrate for bacteria and other aquatic life which filter nutrients and particulates from the water. Stands also reduce flow velocity and promote settling of suspended sediments.

__Likely Future Conditions__

Conditions are favorable for continued rapid expansion of Phragmites throughout much of the Muddy River. Shallow water, lack of heavy shading, nutrient rich sediments, slow current, and low salinity provide near optimal conditions for Phragmites growth. Although the river was dredged to a four foot depth in 1963, sedimentation has reduced water depth to three feet or less throughout most of the river. Existing stands in the river typically grow in up to 3 feet of water, so water depth is not likely to greatly impede Phragmites expansion. Lack of shading by trees along most of the river, particularly between Netherlands Road and the Chapel Street Foot Bridge also favors rapid Phragmites growth. Moderate shading at some locations may slow, but not prevent expansion of existing stands or establishment of new stands. Sediment nutrient levels are high, and responsible for robust growth of existing stands. Phragmites are unlikely to colonize a few areas, such as deep water habitat near the Park Drive culvert, the steeply sloped, heavily shaded western channel near Riverwalk Island, and the shaded, colonized reach downstream of the Leverett Pond outlet.

Assuming that no control measures are implemented, Phragmites could occupy more than half of the river surface (i.e > 4 acres) and at least 75 percent of the river shoreline within 10-20 years. In most of the river, water depth is currently shallow enough, or likely to shoal sufficiently in the future, to allow Phragmites growth across the entire river.

Two young Phragmites stands are established downstream of Netherlands Road. Lack of shade and shallow water depth suggest that these stands will rapidly expand unless control measures are implemented.

BACK BAY FENS SECTION OF THE MUDDY RIVER

Past and Current Conditions

Olmstead designed the Back Bay Fens to be brackish, and they were originally planted with saltmarsh vegetation (Zaitzevsky, 1982). Phragmites probably did not occur in the Fens until after 1910 when completion of the old Charles River Dam in 1910 greatly reduced salinity. Aerial photographs show that Phragmites was well established in the Northern Basin by 1951, occurring along about one-third of the shoreline and occupying about 0.3 acres. Only small isolated stands were present in the Southern Basin, or elsewhere in the Fens upstream of Agassiz Road.

By 1977, Phragmites occupied about 2.2 acres in the Northern Basin and 0.2 acres in the Southern Basin. Phragmites currently occur along about 90 percent of the Northern Basin shoreline and occupy about 2.6 acres of former open water habitat. Expansion appears to have slowed somewhat in recent years, probably since most suitable shallow water habitat (i.e. < 3 ft. deep) has already been colonized. Phragmites currently occur along about one-half of the Southern Basin shoreline and occupy about 0.7 acres. A few small stands totally < 0.1 acre occurs elsewhere in the Fens upstream of the Aggasiz Bridge (see Plate F-2).

As in the Muddy River, Phragmites stands in the Fens are extremely robust (maximum shoot height is 6-7 meters). The stands have eliminated scenic vistas envisioned by Olmstead and strongly detract from the aesthetics of the area. Phragmites also pose a threat to public safety. Numerous assaults have occurred in or near the dense stands growing near the public Victory Gardens.

Phragmites tend to occur in dense, monospecific stands, which have limited wildlife habitat value. Phragmites preclude growth of other wetland plants such as cattail, bulrush, pickerlweed, and arrowhead which are more beneficial to wildlife and visually less obtrusive. On the positive side, Phragmites do provide some cover for wildlife.

Likely Future Conditions

Conditions in the Fens are favorable for continued Phragmites expansion. A substantial amount of open water with depth less than 3 feet is present, and vulnerable to colonization. Locations that appear most vulnerable include near shore areas upstream of the lagoon and the remainder of the Southern Basin shorline. The middle section of the Southern Basin is shallow, but may not be vulnerable to rapid Phragmites expansion because bottom sediments are soft. Wave action, however, may also limit Phragmites expansion in this area. Potential for Phragmites expansion is limited in the Northern Basin, where much of the remaining open water is generally deeper than 3 feet. Phragmites, however, could soon extend across the Northern Basin at a point about halfway between the Agassiz Bridge and the Fire Station where maximum water depth is currently only about 3 feet.

CONTROL MEASURES

Previous studies have recognized the need to control Phragmites growth in the Muddy River and Fens (Lazell et al. 1976; Anderson, 1989; Leahy, 1989; Medcalf and Eddy, 1990; and Walmsley/Pressley, 1991). Potential control measures include the following:

Dredging

Dredging would be an effective way to eradicate Phragmites from the Riverway and Back Bay Fens. Locations with standing water would need to be dredged to a depth of about 2 feet below the existing substrate to assure complete removal of Phragmites rhizomes. Removal of existing Phragmites from the Fens and Muddy River (ca. 5.3 acres) would require dredging of about 18,000 cubic yards of sediment. Disposal options for this material are discussed in Appendix D. Any Phragmites growing in adjacent upland areas (i.e on embankments) would be eradicated by spot herbicide application. Following dredging selective planting of cattail and other emergents would be beneficial to provide wildlife habitat and improve aesthetics. An aggressive long-term monitoring and control program would also be needed to prevent reinfestation.

Dredging to remove Phragmites has several disadvantages. It is the most expensive option and would have the greatest short-term adverse environmental impacts. These include short-term water quality degradation and the probable need to clear some riparian vegetation for construction access. One or more upland sites would be also be needed to dewater the sediments prior to disposal. Dredging operations would probably disrupt public use of the area to a greater extent than other control measures. On the positive side, dredging would provide some long-term water quality improvement due to cocominant removal of contaminated, nutrient rich sediments.

Cutting

Repeated cutting can adequately control, but probably not eradicate, Phragmites. Cutting is particularly well suited when Phragmites are growing in relatively dry areas such as near the Victory Gardens in the Northern Basin. Cutting is much more difficult in standing water, but can be accomplished manually or using specialized equipment. Cutting in standing water in the Muddy River would be very difficult given the exceedingly soft nature of the sediments (at a minimum work would require chestwaders; for some stands a shallow draft boat would be essential). Because new shoots can sprout from cut culms, collection and off-site disposal of the shoots is necessary.

Cutting would be most effective if done in late June or July when belowground energy reserves stored in rhizomes are at or near seasonal lows. Ideally, the initial cutting would be followed up a few weeks latter by a second cutting to further weaken the plants. An aggressive cutting regime practiced over a few years, should greatly reduce Phragmites growth, but would not assure eradication. Eradication, however, could be accomplished by combining cutting with spot herbicide applications (see below). Following eradication, selective planting of cattail and other emergents would be beneficial to provide wildlife habitat and improve aesthetics.

Cutting would be much less expensive than dredging, and would avoid most of the adverse impacts that dredging entails. Cutting alone would not likely eradicate Phragmites, however, and would need to be repeated indefinitely to provide adequate control. A long-term monitoring and control program would also be needed to locate and destroy new infestations.

After stands are cut for a few years it might be possible to adequately control Phragmites biologically by planting cattail. Theoretically, cattail would be able to out compete, and possibly eliminate, the weakened Phragmites. Dobbertein et al. (1992) are experimenting with competitive plantings of saltmarsh vegetation to control Phragmites in coastal marshes, but results of their studies are not yet available.

Herbicides

Repeated application of Rodeo (a glyophosphate) can eradicate Phragmites. For relatively small stands such as those in the Muddy River, application using a backpack sprayer would be appropriate. In larger areas aerial applications are made. Rodeo is most effective if applied after shoots have flowered and are actively translocating photosynthate to rhizomes. Repeat application the following year would be probably necessary for complete eradication. Following eradication, selective planting of cattail and other emergents would be beneficial to provide wildlife habitat and improve aesthetics. A long-term monitoring and control program would be needed prevent reinfestation.

Studies have shown that Rodeo is virtually non toxic to aquatic life, does not accumulate in fish tissues, and degrades quickly after application (see Marks, 1986). Given this information, the degraded nature of the Muddy River, and the environmental benefits of Phragmites eradication, herbicide use in this case seems justified.

Use of herbicides would also be much less costly than either dredging or cutting.

Selective Control

If complete eradication of Phragmites from the Muddy River using dredging or herbicides is not feasible, limited measures should be taken to control Phragmites growth and expansion. These include aggressive control of Phragmites in certain critical areas (e.g. near the Park Drive Culverts), eradication of small, newly established stands, control of lateral expansion of larger stands, and eradication of newly established stands. Control would be provided by cutting or herbicides.

It would be worthwhile to attempt to reduce lateral Phragmites expansion in some areas by planting cattail. Theoretically, competition by a well established cattail stand should be able to slow or prevent Phragmites expansion. It is noteworthy that little encroachment by Phragmites is occurring into existing cattail stands present in the Fens or Riverway near Park Drive.

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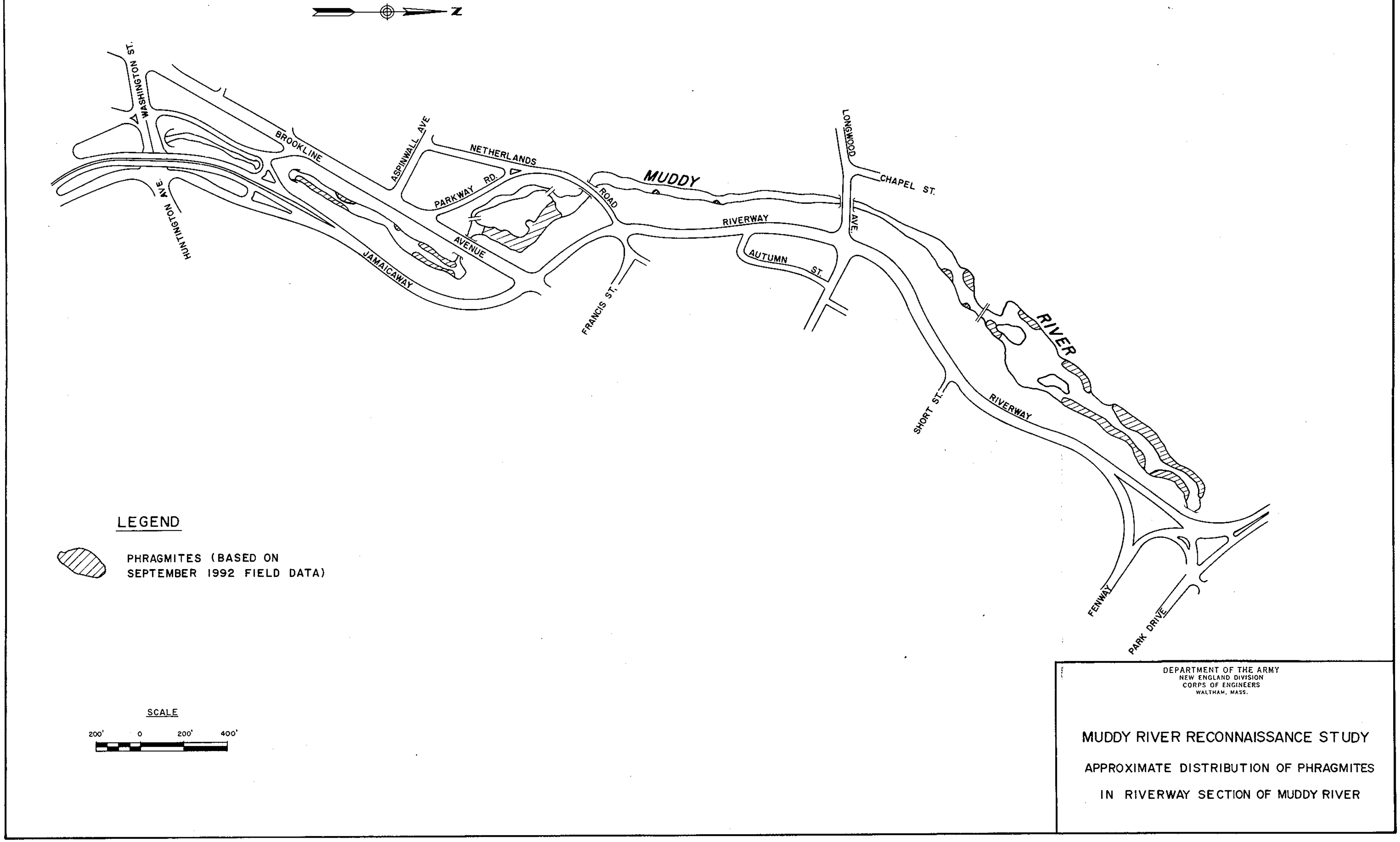
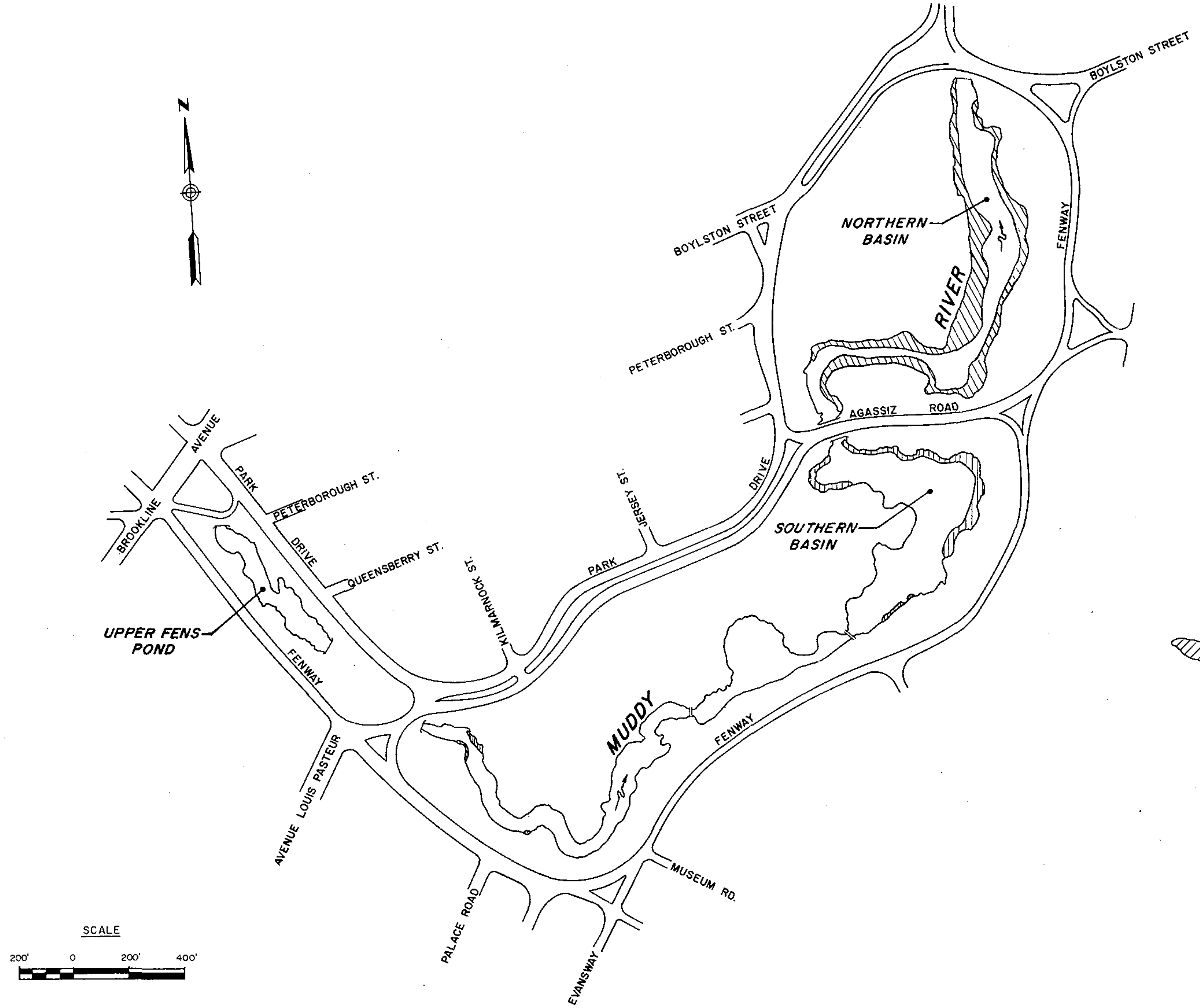


DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER RECONNAISSANCE STUDY

APPROXIMATE DISTRIBUTION OF PHRAGMITES IN RIVERWAY SECTION OF MUDDY RIVER

PLATE F-1



LEGEND

PHRAGMITES (BASED ON 1990 AERIAL PHOTOGRAPHY AND SEPTEMBER 1992 FIELD DATA)

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

MUDDY RIVER RECONNAISSANCE STUDY

APPROXIMATE DISTRIBUTION OF PHRAGMITES IN BACK BAY FENS SECTION OF MUDDY RIVER

PLATE F-2

WATER RESOURCE IMPROVEMENT STUDY

MUDDY RIVER

BOSTON, MASSACHUSETTS

FLOOD DAMAGE REDUCTION PROJECT
RECONNAISSANCE REPORT

APPENDIX G

ECONOMIC ASSESSMENT

PREPARED BY:
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
NEW ENGLAND DIVISION

NOVEMBER 1992

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INTRODUCTION

The purpose of this report is to provide an economic analysis of potential inundation reduction benefit in the Muddy River flood plain. Expected annual damages are calculated for both the natural and modified conditions. The difference in these magnitudes is a measure of inundation reduction. Plans that reduce flooding damages are evaluated. For each plan annual benefits are divided by annual cost to determine a benefit cost ratio. This ratio must be equal to or greater than one for federal participation in water resource improvement projects.

METHODOLOGY

Benefits and costs are made comparable by conversion to average annual equivalents. An interest rate of 8-1/2% as specified in the Federal Register is to be used by Federal agencies in the formulation and evaluation of water and land resource plans for the period 1 October 1991 to 30 September 1992. All costs and benefits are stated at the 1992 price level. The project economic life is considered to be 50 years. The analysis of costs and benefits follows standard U.S. Army Corps of Engineers procedures. The reference document used in the benefit estimation process is ER 1105-2-100, Chapter 6, Section IV, NED Benefit Evaluation Procedures: Urban Flood Damage.

FLOOD DAMAGE SURVEY

A damage survey was conducted in June 1992 for Brookline and Boston, Massachusetts, by flood damage evaluators from the New England Division. The objective of the flood damage survey is to estimate potential flood related damage and losses for each property in the floodplain for each possible flood stage. The floodplain includes residential, commercial, industrial and public structures. For all but residential properties stage damage relationships were developed based upon interviews with occupants and local officials. The stage or elevation at which flood damage begins was determined for each property. Estimates of potential damages were then made from the starting point, in one foot increments of stage, to a level of at least 3 feet above the 1955 flood. Dollar value estimates were made for physical damages to site, structure, contents and utilities. Damages were assumed to start in a building when water reached the first opening. Seepage through the bottom of the foundation was not assumed as the start of damage. Estimates of income losses to businesses and wage losses to employees resulting from a disruption of normal activities was not determined. These nonphysical losses were not estimated because of the difficulty of documentation given the availability of study funds.

Stage damage estimates for residential properties were prepared using typical stage damage relationships for different categories of residential structures. First floor and ground elevations at each building were estimated from spot elevations on topographical mapping.

AFFECTED AREA

The floodplain lies in the communites of Brookline and Boston. There are three damage zones which are designated as follows:

<u>ZONE</u>	<u>AREA</u>
1	Upstream of Park Drive
2	Louis Pasteur Bridge between Park Drive and the Agassiz Bridge
3	Near the Agassiz Bridge

FLOOD DAMAGE COMPUTATION

Flood damages were developed using a program developed in Lotus. Single flood event damage by zones were also determined. Stage-damage information was input for each nonresidential structure. In the case of residences, stage- damage information for each of the residential housing categories was input. The elevation of the first floor and the elevation at which damage starts were also input for each structure. Stage-frequency data for each hydrologic zone were then input. The computer model combined stage-frequency data and stage- damage information to compute damage frequency and expected annual damage by hydrologic zones.

FLOOD DAMAGES

Recurring Losses

Recurring flood losses are those potential damages which are estimated to occur at various flood stages. Under present day development in Boston and Brookline, a recurrence of the 1955 flood (100 year recurrence interval) could cause an estimated $2.7 million in damages to residential, commercial and public structures upstream of Park Drive and $0.3 million in the vicinity of the Agassiz Bridge. There would be no damages in Zone 2, between the Agassiz Bridge and Park Drive. Damages in this zone would not start until elevation 11 NGVD which is above the 100-year event.

Recurring losses by zone are presented in Tables G-1 and G-2. Total recurring losses for all zones are shown in Table G-3.

TABLE G-1
RECURRING LOSSES
BOSTON/BROOKLINE-ZONE 1, Above Park Drive

Flood Elevation (NGVD)	Recurrence Interval (Years)	Structures Affected* (Number)	Loss ($1,000 June 1992)
7.5	10	0	0
8.4	20	0	0
10.3	50	0	0
13.9	100	33	2,700

TABLE G-2
RECURRING LOSSES
BOSTON-ZONE 3, Near the Agassiz Bridge

Flood Elevation (NGVD)	Recurrence Interval (Years)	Structures Affected (Number)	Loss ($1,000 June 1992)
4.8	10	0	0
5.2	20	1	**
6.0	50	2	300
6.8	100	2	300

Notes:

* "Structures Affected" refers to ground level flooding
** Represents less than $50,000 in losses

TABLE G-3
RECURRING LOSSES
All Zones

Recurrence Interval (Years)	Structures Affected (Number)	Loss ($1,000 June 1992)
10	0	0
20	1	**
50	2	300
100	35	3,000

Notes:

* "Structures Affected" refers to ground level flooding
** Represents less than $50,000 in losses

Annual Losses

As mentioned previously, recurring losses relate the dollar value of flood damage to specific flood depths. For the purpose of determining the severity of potential flooding in each damage reach, the statistical concept of "expected value" is employed. Annual losses for each zone are simply the integration of two sets of data: (i) recurring losses displayed in one-foot increments of flood depth from the start of damage to the elevation of the 100 year storm and (ii) the estimated annual percent chance that flood levels will reach each elevation for which recurring losses were estimated. Simply, the probability of reaching a specific flood stage during any given year is multiplied by the corresponding dollar value of damage. The summation of these expected values results in potential annual losses. The effectiveness of each flood reduction plan is measured by the extent to which it reduces annual losses. Annual losses by zone are shown in Table G-4.

TABLE G-4
EXPECTED ANNUAL LOSSES
($1000 June 1992)
BOSTON/BROOKLINE

Zone		Total
1		35.0
2		0.0
3		6.0
	Total	41.0

IMPROVEMENT PLANS

There are two improvement plans evaluated in this analysis. The first which is referred to as the Comprehensive Plan, includes dredging the river in the Back Bay Fens area and increasing the capacity of drainage culverts along the river. The channel would be dredged to a depth of -4 feet NGVD with a width of 30 feet. Culverts upstream of the Brookline Avenue Gate House would be increased from 2-6 foot diameter to 20 foot wide by 10 foot high concrete box culvert. In Option A, the culvert would be 535 feet long. In Option B, the culvert would be 200 feet long with 335 feet of open channel. Two 6-foot culverts at the Louis Pasteur Bridge would be replaced by an open channel -4.0 NGVD by 30 feet.

The second plan is referred to as Alternative 2, the Minimum Plan. This plan would only replace the two 6-foot culverts upstream of the Brookline Avenue Gate House. As in Alternative 1, the culvert would be 535 feet long in Option A, and in Option B, it would be 200 feet long combined with an open channel for the remaining 335 feet.

ECONOMIC BENEFIT ESTIMATION

Economic benefit is measured as inundation reduction. Inundation reduction refers to physical damages to buildings and contents including furnishings, equipment, materials and products and loss of rail service. Benefits are shown in Table G-5 by zone. Total annual benefit for all zones for the Comprehensive Plan is estimated to be $40,000. The Minimum Plan has a project benefit of $29,000 which is attributed to Zone 1.

TABLE G-5
INUNDATION REDUCTION

Alternative 1 - Comprehensive Plan

Zone	Damages Natural	Damages Modified	Benefit
1	$35,000	$0	$35,000
3	6,000	1,000	5,000

Alternative 2 - Minimum Plan

Zone	Damages Natural	Damages Modified	Benefit
1	$35,000	$6,000	$29,000
3	6,000	1,000	0

PLAN JUSTIFICATION

A plan must have a benefit cost ratio greater than one, or net benefit greater than zero, to be justified. Table G-6 displays plan benefit and cost. As cost exceeds benefit for each plan, the benefit cost ratio is less than one and the plans are not economically justified.

TABLE 6
PLAN JUSTIFICATION

	Alternative 1 Comprehensive Plan		Alternative 2 Minimum Plan	
	Option A	Option B	Option A	Option B
Annual Benefit	$40,000	$40,000	$29,000	$29,000
Annual Cost	$1,210,000	$1,170,000	$148,700	$105,900
Benefit Cost Ratio	0.03	0.03	0.20	0.27